SPECIFICATION

CHANNEL ESTIMATION DEVICE AND METHOD, DEMODULATION DEVICE AND

METHOD, AND FADING FREQUENCY DECISION DEVICE AND METHOD

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TECHNICAL FIELD

The present invention relates to a channel estimation device and method, a demodulation device and method, and a fading frequency decision device and method. More 10 specifically, the present invention relates to a channel estimation device, a demodulation device, or the like that is applicable to a mobile communication method for transmitting sounds and data in a fast fading environment. In addition, the present invention relates to a 15 demodulation device and method in conformity with the CDMA method which carries out multidimensional connections by diffusing data to signals over a broad band using a diffusion code operating at a rate higher than a data rate.

20 BACKGROUND ART

In a mobile communication environment, the amplitude or phase varies due to Rayleigh fading associated with movement of the relative locations of a mobile station and a ground station. According to the phase modulation 25 method for transmitting information using a carrier phase, differential coding is generally used to load information on relative phases of a preceding and a following symbols,

and a receiver carries out delayed detection to identify
and determine the information data. This delayed
detection, however, differentially codes the transmitted
data as described above, whereby one-bit error within a
5   wireless section corresponds to a two-bit error in the
information data. Thus, at the same signal power to
interference/noise power ratio (SNIR), the two-phase phase
modulation method (BPSK modulation) has a higher reception
error rate than synchronous detection by 3 dB.

10   In addition, absolute synchronous detection that
identifies and determines an absolute phase of a received
signal for each symbol has an efficient reception
characteristic, but it is difficult to determine the
absolute phase in a Rayleigh fading environment.

15   To solve this problem, a method has been proposed
which inserts pilot symbols between data symbols so as to
use these pilot symbols to estimate a channel for the data
symbols. One of the methods for inserting pilot symbols,
for example, time-multiplexes data symbols and pilot
20 symbols into one channel (time multiplexing method; FIG.
16). Documents 1 to 3, which will be cited below, propose
channel estimation methods using this time multiplexing
method.

The document 1 (Electronic Information
25 Communication Society Journal Vol. J72-B-11, No.1, pp. 7
to 15, January 1989, SANPEI "Land Mobile Communication
16QAM Fading Distortion Compensation") proposes a method

for solving the above problem by estimating and compensating for fading distortion using pilot symbols inserted between data symbols (information symbols) at a fixed cycle and the phases of which are known. This method inserts the pilot symbols into a communication channel at the rate of one pilot symbol per several data symbols to estimate a transmission path based on received phases of the pilot symbols. Signals received during each pass of each transmitter are measured at pilot symbols before and after a desired data symbol section for amplitude and phase, and the measured values are interpolated to estimate and compensate for transmission path variations within the data symbol section.

Document 2 (Electronic Information Communication Society Technical Report RCS97-74, ANDO at el. "RAKE Reception Using the Multislot Weighted Averaging Channel Estimation Method with Pilot Symbols in DS-CDMA") proposes a method for carrying out more accurate channel estimation using more pilot symbols. A channel for data symbols is estimated using pilot symbols inserted between data symbols at a fixed cycle. Specifically, pilot symbols (estimated complex fading envelope) in a plurality of slots before and after a slot for which a channel is estimated are averaged (in-phase addition), and the average value is subjected to weighted averaging using a weighting factor to obtain a channel estimated value. The channel estimation accuracy is thereby improved to prevent thermal

noise or multipass interference and interference from other stations.

Document 3 (Electronic Information Communication Society Technical Report RCS98-20, ABETA at el.
"Characteristics of the DC-CDMA Adaptive Plural Symbol Weighted Averaging Pilot Channel Transmission Path Estimation Method") proposes a method of adaptively controlling a weighting factor to reduce the effects of thermal noise while improving the capability of following fading variations. According to this method, channel estimation involves weighted averaging, and this weighting factor is sequentially varied using an adaptive signal to determine an optimal weighting factor.

The pilot symbol insertion methods include not only the time multiplexing method but also a parallel time multiplexing method (FIG. 1) and a parallel method (FIG. 22) that time-multiplex pilot symbols into a control channel parallel-multiplexed for a data channel.

For the parallel time multiplexing method, it is desirable to execute accurate channel estimation by subjecting the pilot symbols to weighted averaging to calculate a channel estimated value for the data symbols in the data channel.

In addition, according to the methods in Documents 1 to 3, channel variations within each slot are assumed to be small, and the same pilot symbol is used for all the data symbols within one slot to obtain the same channel

estimated value. Consequently, the characteristics are disadvantageously degraded during fast fading.

Further, the method in the Document 2 provides a fixed weighting factor, and when the weighting factor for slots temporally remote from a desired slot is increased to reduce the effects of thermal noise, the capability of following fading variations is disadvantageously degraded, thereby causing the channel estimation accuracy to be degraded. Another problem of the method in the Document 3 is that despite the solution of the problem of the Document 2, the use of the adaptive signal process may make the configuration of a demodulation device complicated.

In the mobile communication environment, the amplitude or phase varies due to Rayleigh fading associated with movement of the relative locations of a mobile station and a ground station. The synchronous detection process using pilot signals is known as a method for compensating for the variations of the amplitude or phase to effectively synthesize multiple passes.

According to this method, a transmitter transmits a known pilot signal, while a receiver demodulates and temporally averages this pilot signal to estimate a channel. Then, the estimated channel vector is used to correct a phase of a data signal, which is then subjected to RAKE synthesis, thereby achieving demodulation using power of the received signal.

Since the channel estimation accuracy directly

affects data quality, averaging must be carried out using appropriate temporal sections and an appropriate weight sequence. One sequence that improves the channel estimation accuracy is conventionally used as the weight sequence.

When the receiver estimates a channel, the channel estimation accuracy can be improved to enable high-quality communication, by using an appropriate weight sequence to average pilot signals. The appropriate weight sequence, however, depends on propagation conditions, principally, the movement speed, as described above.

That is, at a lower movement speed, channel variations occur at a lower speed, so that a weight sequence that increases the averaging time is effective, whereas at a higher movement speed, fast channel variations must be followed, so that a weight sequence that reduces the averaging time to some degree is effective.

However, the known channel estimation method using only the one weight sequence fails to enable averaging suitable for every movement speed, resulting in degradation of communication quality, an increase in transmission power required, a decrease in communication capacity achieved.

In addition, methods for varying the weight sequence depending on the movement speed include a method of detecting the movement speed to vary the weight sequence depending on the detected speed. A problem of this method,

however, is that if the speed detection accuracy or the detection following capability is degraded, improvement of communication quality, a reduction in transmission power required, and an increase in capacity cannot be

5   realized.

DISCLOSURE OF THE INVENTION

It is an object of the present invention to carry out accurate channel estimation in the parallel time

10   multiplexing method by subjecting pilot symbols to weighted averaging to calculate a channel estimated value for data symbols in a data channel.

It is another object of the present invention to carry out accurate channel estimation by dividing data symbols

15   within a slot into a plurality of data symbol sections, selecting pilot symbols appropriate for calculation of a channel estimated value for data symbols within each of the data symbol sections, and subjecting the pilot symbols to weighted averaging to calculate the channel estimated

20   value for the data symbols in each data symbol section.

It is yet another object of the present invention to decide a fading frequency based on an inner product value of the pilot symbols. It is still another object of the present invention to realize channel estimation optimal

25   for the fading frequency using a simpler configuration.

It is still another object of the present invention to directly determine from reception quality, weight

sequences effective on various movement speeds for use, thereby improving communication quality, reducing the amount of transmission power required, and increasing the communication capacity.

5   In order to accomplish the object aforementioned, according to the invention as claimed in claim 1, a channel estimation device comprises:

weighting factor generating means for generating weighting factors for weighting and averaging pilot

10   symbols, which are time multiplexed with a control channel, which is parallel multiplexed with a data channel; and

channel estimation value calculating means for weighting and averaging the pilot symbols using the weighting factors and calculating a channel estimation

15   value of data symbols of the data channel.

According to the invention as claimed in claim 2, in the channel estimation device as claimed in claim 1, the weighting factor generating means generates weighting factors to be used for weighting and averaging mean values

20   of the pilot symbols in a plurality of slots of the control channel, and the channel estimation value calculating means weights and averages the mean values of the pilot symbols using the weighting factors and calculates the channel estimation value of the data symbols of the data

25   channel.

According to the invention as claimed in claim 3, in the channel estimation device as claimed in claim 1 or 2,

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the weighting factors are determined according to the positions of the pilot symbols in the slots of the control channel.

According to the invention as claimed in claim 4, in the channel estimation device as claimed in any one of claims 1-3, the weighting factor generating means divides the data symbols in the slots of the data channel into a plurality of data symbol sections, selects the pilot symbols appropriate for calculating the channel estimation value of the data symbols in each of the data symbol sections, and generates the weighting factors to be used for weighting and averaging the pilot symbols; and the channel estimation value calculating means takes weighted average of the pilot symbols using the weighting factors and calculates the channel estimation value of the data symbols of each of the data symbol sections.

According to the invention as claimed in claim 5, in the channel estimation device as claimed in claim 4, wherein in order to calculate the channel estimation value of the data symbols of the last data symbol section of the i-th (i: integer) slot and to calculate the channel estimation value of the data symbols of the first data symbol section of the (i+1)-th slot, the weighting factor generating means selects the same pilot symbol and generates the weighting factors to be used for weighting and averaging the pilot symbols.

According to the invention as claimed in claim 6, the

channel estimation device as claimed in any one of claims 1-5, further comprises:

fading frequency decision means for deciding the fading frequency based on an inner product value of the pilot symbols; and

factor altering means for altering the factors that are used in taking the weighted average according to the fading frequency decided by the fading frequency decision means.

According to the invention as claimed in claim 7, in the channel estimation device as claimed in any one of claims 1-6, a transmission rate of the data channel differs from the transmission rate of the control channel.

According to the invention as claimed in claim 8, a demodulation device comprises:

weighting factor generating means for generating weighting factors to be used for weighting and averaging pilot symbols being time multiplexed in a control channel that was parallel multiplexed together with a data channel;

channel estimation value calculating means for weighting and averaging the pilot symbols using the weighting factors and for calculating a channel estimation value of data symbols of the data channel; and

channel variation compensating means for compensating channel variation of the data symbols using the channel estimation value calculated by the channel estimation value calculating means.

According to the invention as claimed in claim 9, a fading frequency decision device comprises:

inner product value calculating means for calculating an inner product value of pilot symbols, which are time multiplexed with a control channel, which is parallel multiplexed with a data channel; and

decision means for deciding a fading frequency based on the inner product value calculated by the inner product value calculating means.

According to the invention as claimed in claim 10, in the fading frequency decision device as claimed in claim 9,

the inner product value calculating means comprises:

normalizing means for normalizing mean values of the pilot symbols in each of two slots of the control channel;

inner product value calculation executing means for calculating an inner product value of the mean values of the two pilot symbols normalized by the normalizing means; and

inner product value averaging means for averaging inner product values calculated by the inner product value calculation executing means over a plurality of slots of the control channel, and

the decision means comprises

decision executing means for deciding the fading frequency by comparing the inner product value

averaged by the inner product value averaging means and a threshold value.

According to the invention as claimed in claim 11, in the fading frequency decision device as claimed in claim 10, when the inner product value averaged by the inner product value averaging means is larger than a certain constant value, the fading frequency decision device performs the normalizing, the inner product value calculation, and the inner product value averaging on mean values of the pilot symbols in each of two slots having a farther interval in the control channel, and decides the fading frequency by comparing the averaged inner product value so obtained and a threshold value corresponding to the farther interval.

According to the invention as claimed in claim 12, in the fading frequency decision device as claimed in claim 9,

the inner product value calculating means comprises:

normalizing means for normalizing the mean values of the pilot symbols in each of two slots of the control channel with respect to each of multipath signals to be used for RAKE combining;

inner product value calculation executing means for calculating the inner product value of the mean values of the two pilot symbols normalized by the normalizing means with respect to each of the multipath signals;

first inner product value averaging means for averaging the inner product values of each of the multipath signals calculated by the inner product value calculation executing means; and

second inner product value averaging means for averaging the inner product values averaged by the first inner product value averaging means over a plurality of slots of the control channel, and

the decision means comprises

decision executing means for deciding the fading frequency by comparing the inner product value averaged by the second inner product value averaging means and a threshold value.

According to the invention as claimed in claim 13, in the fading frequency decision device as claimed in claim 12, when the inner product value averaged by the second inner product value averaging means is larger than a certain constant value, the fading frequency decision device performs the normalizing, the inner product value calculation, averaging of the inner product values of each of the multipath signals, and averaging of the inner product values over the plurality of slots on the mean values of the pilot symbols in each of two slots having a farther interval in the control channel, and decides the fading frequency by comparing the averaged inner product value so obtained and a threshold value corresponding to the farther interval.

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According to the invention as claimed in claim 14, in the fading frequency decision device as claimed in claim 9,

the inner product value calculating means comprises:

normalizing means for normalizing the mean values of the pilot symbols in each of two slots in the control channel;

inner product value calculation executing means for calculating the inner product value of the mean values of the two pilot symbols normalized by the normalizing means for two or more cases with varying inner product measuring interval; and

inner product value averaging means for averaging the inner product value calculated by the inner product value calculation executing means over a plurality of slots of the control channel with respect to each of the inner product measuring intervals, and

the decision means comprises

decision executing means for deciding the fading frequency using the inner product value for each of the inner product measuring intervals averaged by the inner product value averaging means.

According to the invention as claimed in claim 15, in the fading frequency decision device as claimed in claim 14, further comprising difference calculating means for calculating the difference of the inner product values for two inner product measuring intervals averaged by the inner

product value averaging means, wherein the decision executing means decides the fading frequency using also the difference calculated by the difference calculating means.

5   According to the invention as claimed in claim 16, in the fading frequency decision device as claimed in claim 9,

the inner product value calculating means comprises:

normalizing means for normalizing mean values
10 of the pilot symbols in each of two slots in the control channel with respect to each of multipath signals to be used for RAKE combining;

inner product value calculation executing means for calculating the inner product value of the mean
15 values of the two pilot symbols normalized by the normalizing means for two or more cases with varying inner product measuring interval with respect to each of the multipath signals;

first inner product value averaging means for
20 averaging the inner product values of each of the multipath signals calculated by the inner product value calculation executing means with respect to each of the inner product measuring intervals; and

second inner product value averaging means for
25 averaging the inner product values averaged by the first inner product value averaging means over a plurality of slots of the control channel with respect to each of the

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inner product measuring intervals, and

the decision means comprises

decision executing means for deciding the
fading frequency using the inner product value for each
5   of the inner product measuring intervals averaged by the
second inner product value averaging means.

According to the invention as claimed in claim 17,
the fading frequency decision device as claimed in claim
16, further comprises difference calculating means for
10   calculating the difference of the inner product values for
two inner product measuring intervals averaged by the
second inner product value averaging means, wherein the
decision executing means decides the fading frequency
using also the difference calculated by the difference
15   calculating means.

According to the invention as claimed in claim 18,
a channel estimation device for calculating a channel
estimation value of data symbols using pilot symbols in
a channel in which the data symbols and the pilot symbols
20   are time multiplexed, comprises:

weighting factor generating means for dividing data
symbols in a slot of the channel into a plurality of data
symbol intervals, selecting pilot symbols suitable for
calculation of a channel estimation value of data symbols
25   during each data symbol interval and generating weighting
factors for weighting and averaging the pilot symbols; and

channel estimation value calculating means for

weighting and averaging the pilot symbols using the weighting factors and calculating a channel estimation value of data symbols during each data symbol interval.

According to the invention as claimed in claim 19, in the channel estimation device as claimed in claim 18, in order to calculate the channel estimation value of the data symbols in the last data symbol section in the i-th (i: integer) slot and to calculate the channel estimation value of the data symbols of the first data symbol section in the (i+1)-th slot, the weighting factor generating means selects the same pilot symbol and generates the weighting factors to be used for weighting and averaging the pilot symbols.

According to the invention as claimed in claim 20, in the channel estimation device as claimed in claim 18 or 19, the weighting factor generating means generates the weighting factors to be used for weighting and averaging mean values of the pilot symbols for each of the plurality of slots of the channel, and the channel estimation value calculating means takes weighted average of the mean values of the pilot symbols using the weighting factors and calculates the channel estimation value of the data symbols in each of the data symbol sections.

According to the invention as claimed in claim 21, in the channel estimation device as claimed in any one of claims 18-20, the weighting factors are determined according to positions of the pilot symbols in the slots

of the channel.

According to the invention as claimed in claim 22, the channel estimation device as claimed in any one of claims 18-21, further comprises:

5   fading frequency decision means for deciding the fading frequency based on the inner product value of the pilot symbols; and

factor altering means for altering the factors to be used for taking the weighted averaging according to the
10   fading frequency decided by the fading frequency decision means.

According to the invention as claimed in claim 23, a demodulation device comprises:

weighting factor generating means for dividing
15   data symbols in the slots of a channel into which the data symbols and pilot symbols are time multiplexed into a plurality of data symbol sections, selecting pilot symbols appropriate for calculating the channel estimation value of the data symbols in each of the data symbol sections,
20   and generating the weighting factors to be used for weighting and averaging the pilot symbols;

channel estimation value calculating means for weighting and averaging the pilot symbols using the weighting factors and calculating the channel estimation
25   value of the data symbols in each of data symbol sections; and

channel variation compensating means for

compensating channel variation of the data symbols using the channel estimation value calculated by the channel estimation value calculating means.

According to the invention as claimed in claim 24, a fading frequency decision device comprises:

inner product value calculating means for calculating an inner product value of pilot symbols in a channel in which data symbols and the pilot symbols are time multiplexed; and

decision means for deciding a fading frequency based on the inner product value calculated by the inner product value calculating means.

According to the invention as claimed in claim 25, in the fading frequency decision device as claimed in claim 24,

the inner product value calculating means comprises:

normalizing means for normalizing mean values of the pilot symbols in each of two slots of the channel;

inner product value calculation executing means for calculating the inner product value of the mean values of the two pilot symbols normalized by the normalizing means; and

inner product value averaging means for averaging the inner product values calculated by the inner product value calculation executing means over a plurality of slots of the channel, and

the decision means comprises

decision executing means for deciding the fading frequency by comparing the inner product value averaged by the inner product value averaging means and a threshold value.

According to the invention as claimed in claim 26, in the fading frequency decision device as clamed in claim 25, when the inner product value averaged by the inner product value averaging means is larger than a certain constant value, the fading frequency decision device performs the normalizing, the inner product value calculation, and the inner product value averaging on mean values of the pilot symbols in each of two slots having a farther interval in the control channel, and decides the fading frequency by comparing the averaged inner product value so obtained and a threshold value corresponding to the farther interval.

According to the invention as claimed in claim 27, in the fading frequency decision device as claimed in claim 24,

the inner product value calculating means comprises:

normalizing means for normalizing mean values of the pilot symbols in each of two slots of the control channel with respect to each of multipath signals to be used for RAKE combining;

inner product value calculation executing means for calculating the inner product value of the mean values of the two pilot symbols normalized by the

normalizing means with respect to each of the multipath signals;

first inner product value averaging means for averaging the inner product values of each of the multipath signals calculated by the inner product value calculation executing means; and

second inner product value averaging means for averaging the inner product values averaged by the first inner product value averaging means over a plurality of slots of the channel, and

the decision means comprises

decision executing means for deciding the fading frequency by comparing the inner product value averaged by the second inner product value averaging means and a threshold value.

According to the invention as claimed in claim 28, in the fading frequency decision device as claimed in claim 27, when the inner product value averaged by the second inner product value averaging means is larger than a certain constant value, the fading frequency decision device performs the normalizing, the inner product value calculation, averaging of the inner product values of each of the multipath signals, and averaging of the inner product values over the plurality of slots on the mean values of the pilot symbols in each of two slots having a farther interval in the control channel, and decides the fading frequency by comparing the averaged inner product

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value so obtained and a threshold value corresponding to the farther interval.

According to the invention as claimed in claim 29, in the fading frequency decision device as claimed in claim 24,

the inner product value calculating means comprises:

normalizing means for normalizing the mean values of the pilot symbols in each of two slots of the channel;

inner product value calculation executing means for calculating the inner product value of the mean values of the two pilot symbols normalized by the normalizing means for two or more cases with varying inner product measuring interval; and

inner product value averaging means for averaging the inner product values calculated by the inner product value calculation executing means over a plurality of slots of the control channel with respect to each of the inner product measuring intervals, and

the decision means comprises

decision executing means for deciding the fading frequency using the inner product value for each of the inner product measuring intervals averaged by the inner product value averaging means.

According to the invention as claimed in claim 30, the fading frequency decision device as claimed in claim 29, further comprises difference calculating means for

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calculating the difference of the inner product values for two inner product measuring intervals averaged by the inner product value averaging means, wherein the decision executing means decides the fading frequency also using the difference calculated by the difference calculating means.

According to the invention as claimed in claim 31, in the fading frequency decision device as claimed in claim 24,

the inner product value calculating means comprises:

normalizing means for normalizing mean values of the pilot symbols in each of two slots of the channel with respect to each of multipath signals to be used for RAKE combination;

inner product value calculation executing means for calculating the inner product value of the mean values of two pilot symbols normalized by the normalizing means for two or more cases with varying inner product measuring interval with respect to each of the multipath signals;

first inner product value averaging means for averaging the inner product value of each of the multipath signals calculated by the inner product value calculation executing means with respect to each of the inner product measuring intervals; and

second inner product value averaging means for

averaging the inner product values averaged by the first
inner product value averaging means over a plurality of
slots of the control channel with respect to each of the
inner product measuring intervals, and

5   the decision means comprises

decision executing means for deciding the
fading frequency using the inner product value for each
of the inner product measuring intervals averaged by the
second inner product value averaging means.

10   According to the invention as claimed in claim 32,
in the fading frequency decision device as claimed in claim
31, further comprising difference calculating means for
calculating the difference of the inner product values for
two inner product measuring intervals averaged by the
15   second inner product value averaging means, wherein the
decision executing means decides the fading frequency also
using the difference calculated by the difference
calculating means.

According to the invention as claimed in claim 33,
20   a channel estimation device that calculates a channel
estimation value of data symbols of a data channel using
pilot symbols of a pilot channel which is parallel
multiplexed with the data channel, comprises:

weighting factor generating means for dividing data
25   symbols in the channel into a plurality of data symbol
intervals, selecting pilot symbols suitable for
calculation of a channel estimation value of data symbols

during each data symbol interval and generating weighting

factors for weighting and averaging the pilot symbols; and

channel estimation value calculating means for

weighting and averaging the pilot symbols using the

5 weighting factors and calculating a channel estimation

value of data symbols during each data symbol interval.

According to the invention as claimed in claim 34,

in the channel estimation device as claimed in claim 33,

the weighting factor generating means generates the

10 weighting factors to be used for weighting and averaging

mean values of the pilot symbols in each of a plurality

of sections in the pilot channel, and the channel

estimation value calculating means takes weighted average

of the mean values of the pilot symbols using the weighting

15 factors and calculates the channel estimation value of the

data symbols in each of the data symbol sections.

According to the invention as claimed in claim 35,

the channel estimation device as claimed in claim 33 or

34, further comprises:

20 fading frequency decision means for deciding the

fading frequency based on the inner product value of the

pilot symbols; and

factor altering means for altering the factors to

be used for taking the weighted average according to the

25 fading frequency decided by the fading frequency decision

means.

According to the invention as claimed in claim 36,

in the channel estimation device as claimed in any one of claims 33-35, wherein a transmission rate of the data channel differs from the transmission rate of the pilot channel.

According to the invention as claimed in claim 37, a demodulation device comprises:

weighting factor generating means for dividing data symbols of a data channel into a plurality of data symbol sections, selecting pilot symbols of a pilot channel that was parallel multiplexed together with the data channel, appropriate for calculating the channel estimation value of the data symbols in each of the data symbol sections, and generating weighting factors to be used for weighting and averaging the pilot symbols;

channel estimation value calculating means for weighting and averaging the pilot symbols using the weighting factors and calculating the channel estimation value of the data symbols of each of the data symbol sections; and

channel variation compensating means for compensating the channel variation of the data symbols using the channel estimation value calculated by the channel estimation value calculating means.

According to the invention as claimed in claim 38, a fading frequency decision device comprises:

inner product value calculating means for calculating an inner product value of pilot symbols in a

pilot channel which is parallel multiplexed with a data channel; and

decision means for deciding a fading frequency based on the inner product value calculated by the inner product value calculating means.

According to the invention as claimed in claim 39, in the fading frequency decision device as claimed in claim 38,

the inner product value calculating means comprises:

normalizing means for normalizing the mean value of the pilot symbols in each of two sections of the pilot channel;

inner product value calculation executing means for calculating an inner product value of mean values of the two pilot symbols normalized by the normalizing means; and

inner product value averaging means for averaging the inner product values calculated by the inner product value calculation executing means over a plurality of sections of the channel, and

the decision means comprises

decision executing means for deciding the fading frequency by comparing the inner product value averaged by the inner product value averaging means and a threshold value.

According to the invention as claimed in claim 40, in the fading frequency decision device as claimed in claim

39, when the inner product value averaged by the inner product value averaging means is larger than a certain constant value, the frequency decision device performs the normalizing, the inner product value calculation, and the averaging of the inner product values with respect to the mean values of the pilot symbols in each of two sections having a farther interval in the pilot channel, and decides the fading frequency by comparing the averaged inner product value so obtained and a threshold value corresponding to the farther interval.

According to the invention as claimed in claim 41, in the fading frequency decision device as claimed in claim 38,

the inner product value calculating means comprises:

normalizing means for normalizing the mean values of the pilot symbols in each of the two sections of the pilot channel with respect to each of multipath signals to be used for RAKE combining;

inner product value calculation executing means for calculating the inner product value of the mean values of the two pilot symbols normalized by the normalizing means with respect to each of the multipath signals;

first inner product value averaging means for averaging the inner product values of respective paths of the multipath calculated by the inner product value calculation executing means; and

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second inner product value averaging means for averaging the inner product values averaged by the first inner product value averaging means over a plurality of sections of the pilot channel, and

5   the decision means comprises

decision executing means for deciding the fading frequency by comparing the inner product value averaged by the second inner product value averaging means and a threshold value.

10   According to the invention as claimed in claim 42, in the fading frequency decision device as claimed in claim 41, when the inner product value averaged by the second inner product value averaging means is larger than a certain constant value, the fading frequency decision

15   device performs the normalizing, the inner product value calculation, averaging of the inner product values of each of the multipath signals, and averaging of the inner product values over the plurality of sections with respect to the mean values of the pilot symbols in each of two

20   sections having a farther interval in the pilot channel, and decides the fading frequency by comparing the averaged inner product value so obtained and a threshold value corresponding to the farther interval.

According to the invention as claimed in claim 43,

25   in the fading frequency decision device as claimed in claim 38,

the inner product value calculating means comprises:

normalizing means for normalizing the mean values of the pilot symbols in each of the two sections of the pilot channel;

inner product value calculation executing
5   means for calculating the inner product value of the mean values of the two pilot symbols normalized by the normalizing means for two or more cases with varying inner product measuring interval; and

inner product value averaging means for
10   averaging the inner product vales calculated by the inner product value calculation executing means over a plurality of sections of the control channel with respect to each of the inner product measuring intervals, and

the decision means comprises
15   fading frequency decision means for deciding the fading frequency using the inner product value for each of the inner product measuring intervals averaged by the inner product value averaging means.

According to the invention as claimed in claim 44,
20   in the fading frequency decision device as claimed in claim 43, further comprising difference calculating means for calculating the difference of the inner product values for the two inner product measuring intervals averaged by the inner product value averaging means, wherein the decision
25   executing means decides the fading frequency using also the difference calculated by the difference calculating means.

According to the invention as claimed in claim 45, in the fading frequency decision device as claimed in claim 38,

the inner product value calculating means comprises:

normalizing means for normalizing the mean values of the pilot symbols in each of the two sections of the pilot channel with respect to each of multipath signals to be used for RAKE combining;

inner product value calculation executing means for calculating the inner product value of the mean values of the two pilot symbols normalized by the normalizing means for two or more cases with varying inner product measuring interval with respect to each of the multipath signals;

first inner product value averaging means for averaging the inner product value for each path of the multipath calculated by the inner product value calculation executing means with respect to each of the inner product measuring intervals; and

second inner product value averaging means for averaging the inner product values averaged by the first inner product value averaging means for a plurality of sections of the control channel with respect to each of the inner product measuring intervals, and

the decision means comprises

decision executing means for deciding the fading frequency using the inner product value for each

of the inner product measuring intervals averaged by the second inner product value averaging means.

According to the invention as claimed in claim 46, the fading frequency decision device as claimed in claim 45, further comprises difference calculating means for calculating the difference of the inner product values for two inner product intervals averaged by the second inner product value averaging means, wherein the decision executing means decides the fading frequency also using the difference calculated by the difference calculating means.

According to the invention as claimed in claim 47, a method for estimating a channel, comprises the steps of:

generating weighting factors to be used for weighting and averaging pilot symbols being time multiplexed in a control channel that was parallel multiplexed together with a data channel; and

averaging the pilot symbols using the weighting factors and calculating a channel estimation value of data symbols of the data channel.

According to the invention as claimed in claim 48, a method for deciding the fading frequency, comprises the steps of:

calculating an inner product value of pilot symbols being time multiplexed in a control channel that was parallel multiplexed together with a data channel; and

deciding the fading frequency based on the inner

product value.

According to the invention as claimed in claim 49, a channel estimation method for calculating a channel estimation value of data symbols using pilot symbols in a channel in which the data symbols and pilot symbols are time multiplexed, comprises the steps of:

dividing the data symbols in the slots of the channel into a plurality of data symbol sections, selecting the pilot symbols appropriate for acquiring the channel estimation value of the data symbols in each of the data symbol sections, and generating weighting factors to be used for weighting and averaging the pilot symbols; and

weighting and averaging the pilot symbols using the weighting factors and calculating the channel estimation value of the data symbols in each of the data symbol sections.

According to the invention as claimed in claim 50, a method for deciding the fading frequency, comprises the step of:

calculating an inner product value of pilot symbols in a channel in which data symbols and pilot symbols are time multiplexed; and

deciding the fading frequency based on the inner product value.

According to the invention as claimed in claim 51, a channel estimation method for calculating a channel estimation value of data symbols of a data channel using

pilot symbols of a pilot channel that was parallel multiplexed together with the data channel, comprises the steps of:

dividing the data symbols of the data channel into

5   a plurality of data symbol sections, selecting pilot symbols appropriate for calculating the channel estimation value of the data symbols in each of the data symbol sections, and generating weighting factors to be used for weighting and averaging the pilot symbols; and

10   weighting and averaging the pilot symbols using the weighting factors and calculating the channel estimation value of the data symbols in each of the data symbol sections.

According to the invention as claimed in claim 52,

15   in a method for deciding the fading frequency, the fading frequency is decided based on an inner product value of pilot symbols of a pilot channel that was parallel multiplexed together with a data channel.

According to the invention as claimed in claim 53,

20   a demodulation device comprises:

channel estimating means for deriving N (N is natural number greater than or equal to two) in number of channel estimation values by weighted averaging of pilot signals in time using N in number of weighted sequences;

25   compensating means for compensating data sequences using the respective channel estimation values;

RAKE combining means for RAKE combining respective

of the N data sequences after compensation; and

reliability judgment means for selecting one data sequence having highest reliability from the N data sequences after RAKE combination.

5 According to the invention as claimed in claim 54, a demodulation device comprises:

channel estimating means for deriving N (N is natural number greater than or equal to two) in number of channel estimation values by weighted averaging of pilot signal

10 in time using N in number of weighted sequences for data sequences of predetermined frame number;

compensating means for compensating data sequence using the respective channel estimation values;

RAKE combining means for RAKE combining of the N data

15 sequences after compensation; and

reliability judgment means for selecting N' (N': natural number, N' < N) in number of weighting sequences from the N data sequence after RAKE combining and selecting one data sequence having the highest reliability from N

20 data sequences,

selection of the N' weighting sequences being performed per a predetermined period, for remaining data sequences until performing the reliability judgement again the channel estimation means deriving N' channel

25 estimation value by weighted averaging in time using N' weighting sequences, the compensating means compensating data sequences using N' channel estimation values, the RAKE

combining means RAKE combining respective of N' data sequences after compensation, and the reliability judgment means selecting one data sequence having the highest reliability from the N' data sequences.

5   According to the invention as claimed in claim 55, in the demodulation device as claimed in claim 53 or 54, the reliability judging means for judging reliability of the data sequence comprises:

error-correction decoding means for performing
10 error-correction decoding of the data sequence after the RAKE combination;

CRC (Cyclic Redundancy Check) bit extracting means for extracting CRC bits added to the data sequence; CRC decoding means for decoding the CRC for the data
15 sequence;

frame error detecting means for detecting the presence or absence of a frame error based on a decoding result of the CRC;

number-of-frame-error counting means for counting
20 the number of the frame errors in a previously-determined measuring time; and

weight sequence and data selecting means for selecting the weight sequence having high reliability and the data sequence that is demodulated using the weight
25 sequence so selected based on the counting result of the frame errors.

According to the invention as claimed in claim 56,

in the demodulation device as claimed in claim 53 or 54, the reliability judging means for judging reliability of the data sequence comprises:

error-correction decoding means for performing

5   error-correction decoding of the data sequence after the RAKE combination;

likelihood information extracting means for extracting likelihood information that is calculated when performing the error-correction decoding of each of the

10   data sequences;

likelihood averaging means for averaging the extracted likelihood information for a previously-determined measuring time; and

weight sequence and data selecting means for

15   selecting the weight sequence having high reliability and the data sequence that is demodulated using the weight sequence so selected based on the averaged likelihood information.

According to the invention as claimed in claim 57,

20   in the demodulation device as claimed in claim 53 or 54, the reliability judging means for judging reliability of the data sequence comprises:

electric power calculating means for calculating electric power of each of the data sequences after the RAKE

25   combination;

electric power averaging means for averaging the calculation result of the electric power for a

previously-determined measuring time; and

weight sequence and data selecting means for selecting the weight sequence having high reliability and data sequence that is demodulated using the weight sequence
5   so selected based on the averaged electric power.

According to the invention as claimed in claim 58, in the demodulation device as claimed in claim 53 or 54, the reliability judging means for judging reliability of the data sequence comprises:

10   signal-to-noise ratio(ratio of a signal power to a noise power) calculating means for calculating a signal-to-noise ratio of each of the data sequences after the RAKE combination;

signal-to-noise ratio averaging means for
15   averaging the calculation result of the signal-to-noise ratio for a previously-determined measuring time; and

weight sequence and data selecting means for selecting the weight sequence having high reliability and the data sequence that is demodulated using the weight
20   sequence so selected based on the averaged signal-to-noise ratio.

According to the invention as claimed in claim 59, in the demodulation device as claimed in claim 53 or 54, the reliability judging means for judging reliability of
25   the data sequence comprises:

error-correction decoding means for performing error-correction decoding of the data sequence after the

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RAKE combination;

CRC bit extracting means for extracting CRC bits added to the data sequence;

CRC decoding means for decoding the CRC for the data
5 sequence;

frame error detecting means for detecting the presence or absence of a frame error based on a decoding result of the CRC;

number-of-frame-error counting means for counting
10 the number of the frame errors in a previously-determined measuring time;

likelihood information extracting means for extracting likelihood information that is calculated when performing error-correction decoding of each of the data
15 sequences;

likelihood averaging means for averaging the extracted likelihood information for a previously-determined measuring time; and

weight sequence and data selecting means for
20 selecting the weight sequence having high reliability and the data sequence that is demodulated using the weight sequence so selected based on the counted number of frame errors of the plurality of data sequences and the averaged likelihood information.

25 According to the invention as claimed in claim 60, in the demodulation device as claimed in claim 53 or 54, the reliability judging means for judging reliability of

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the data sequence comprises:

error-correction decoding means for performing error-correction decoding of the data sequence after the RAKE combination;

5   CRC bit extracting means for extracting CRC bits added to the data sequence;
CRC decoding means for decoding the CRC for the data sequence;

frame error detecting means for detecting the

10   presence or absence of a frame error based on a decoding result of the CRC;

number-of-frame-error counting means for counting the number of the frame errors in a previously-determined measuring time;

15   electric power calculating means for calculating electric power of each of the data sequences after the RAKE combination;

electric power averaging means for averaging the calculation result of the electric power for a

20   previously-determined measuring time; and

weight sequence and data selecting means for selecting the weight sequence having high reliability and the data sequence that is demodulated using the weight sequence so selected based on the number of frame errors

25   and the averaged electric power.

According to the invention as claimed in claim 61, in the demodulation device as claimed in claim 53 or 54,

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the reliability judging means for judging reliability of the data sequence comprises:

error-correction decoding means for performing error-correction decoding of the data sequence after the RAKE combination;

CRC bit extracting means for extracting CRC bits added to the data sequence;

CRC decoding means for decoding the CRC for the data sequence;

frame error detecting means for detecting the presence or absence of a frame error based on a decoding result of the CRC;

number-of-frame-error counting means for counting the number of the frame errors in a previously-determined measuring time;

signal-to-noise ratio calculating means for calculating a signal-to-noise ratio (ratio of a signal power to a noise power) of each of the data sequences after the RAKE combination;

signal-to-noise ratio averaging means for averaging the calculation result of the signal-to-noise ratio for a previously-determined measuring time; and

weight sequence and data selecting means for selecting weight sequence having high reliability and the data sequence that is demodulated using the weight sequence so selected based on the number of frame errors and the averaged signal-to-noise ratio.

According to the invention as claimed in claim 62, a demodulation device comprises:

channel estimating means for weighted averaging of reception pilot signal using a plurality of weighting sequences and deriving a plurality of channel estimation values;

demodulating means for inputting data sequences and outputting a plurality of demodulated data sequences using the plurality of channel estimation values; and

reliability judging means for selecting one demodulated data by making judgment of reliability of the plurality of demodulated data sequences.

According to the invention as claimed in claim 63, in the demodulation device as claimed in claim 62,

the reliability judging means comprises selecting means for selecting predetermined number of the weight sequences from among the plurality of weight sequences based on a judgment result of reliability of the plurality of demodulated data sequences, and

the demodulating means performs the demodulation using only the predetermined number of the weight sequences, when the predetermined number of the weight sequences were selected.

According to the invention as claimed in claim 64, in the demodulation device as claimed in any one of claims 53-63, the pilot signals are time multiplexed in a control channel that was parallel multiplexed together with a data

channel in which the data sequence is contained.

According to the invention as claimed in claim 65, in the demodulation device as claimed in any one of claims 53-63, the pilot signals are time multiplexed in one

5 channel together with the data sequence.

According to the invention as claimed in claim 66, in the demodulation device as described in claim 65, the channel estimating means divides the data sequence in the slots of the channel into a plurality of data sequence

10 sections, selects pilot signals appropriate for calculating the channel estimation value of the data in each of the data sequence sections, and calculates the channel estimation value of the data of each of the data sequence sections by weighting and averaging the selected

15 pilot signals.

According to the invention as claimed in claim 67, in the demodulation device as claimed in any one of claims 53-63, the pilot signals are contained in a pilot channel that was parallel multiplexed together with the data

20 channel containing the data sequence.

According to the invention as claimed in claim 68, in the demodulation device as claimed in claim 67, the channel estimating means divides the data sequence into a plurality of data sequence sections, selects pilot

25 signals appropriate for calculating the channel estimation value of the data in each of the data sequence sections, and calculates the channel estimation value of the data

in each of the data sequence sections by weighting and averaging the selected pilot signals.

According to the invention as claimed in claim 69, a demodulation method comprises:

the step of obtaining N pieces of channel estimation values by time-weighting and averaging the pilot signals using N (N: natural number greater than or equal to 2) sets of weight sequences;

the step of compensating data sequence using each of the channel estimation values;

the step of RAKE combining each of the N sets of the data sequences after the compensation; and

the reliability judgment step of selecting one set of the data sequences having the highest reliability from among the N sets of the data sequences after the RAKE combination.

According to the invention as claimed in claim 70, a demodulation method comprises:

the step of obtaining N (N: natural number greater than or equal to 2) pieces of channel estimation values by time-weighting and averaging pilot signals using N sets of weight sequences with respect to a previously-determined number of frames of data sequence;

the step of compensating the data sequence using each of the channel estimation values;

the step of RAKE combining each of N sets of the data sequences after the compensation; and

the reliability judgment step of selecting N' (N':
natural number; N'<N) sets of the weight sequences having
high reliability from among the N sets of the data sequences
after the RAKE combination and selecting one set of data
5   sequence having the highest reliability from among the N
sets of the data sequences after the RAKE combination,

wherein the selection of the N' sets of the weight
sequences is conducted at regular intervals, and
throughout a period up to a time when the judgment of
10   reliability is made next time, with respect to remaining
part of the data sequence, in the step of estimating the
channel, N' pieces of the channel estimation values are
obtained by time-weighting and averaging the data sequence
using the N' sets of the weight sequences; in the step of
15   compensating, the data sequence is compensated using the
N' pieces of the channel estimation values; in the step
of the RAKE combination, each of the N' sets of the data
sequences after the compensation is RAKE combined; and in
the reliability judgment step, one set of the data sequence
20   having the highest reliability is selected from among the
N' sets of the data sequences.

According to the invention as claimed in claim 71,
in the demodulation method as claimed in claim 69 or 70,
the reliability judgment step comprises the steps of:
25   error-correction decoding the data sequence after
the RAKE combination;

extracting CRC bits added to the data sequence;

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decoding the CRC with respect to the data sequence;

detecting the presence or absence of a frame error based on the demodulation result of the CRC;

counting the number of the frame errors in a

5   previously-determined measuring time; and

selecting the weight sequence having high reliability and the data sequence that is demodulated using the weight sequence so selected based on the counting result of the frame errors.

10   According to the invention as claimed in claim 72, in the demodulation method as claimed in claim 69 or 70, the reliability judgment step comprises the steps of:

error-correction decoding the data sequence after the RAKE combination;

15   extracting likelihood information calculated when performing error-correction decoding of each of the data sequence;

averaging the extracted likelihood information for a previously-determined measuring time; and

20   selecting the weight sequence having high reliability and the data sequence that is demodulated using the weight sequence so selected based on the averaged likelihood information.

According to the invention as claimed in claim 73,

25   in the demodulation method as claimed in claim 69 or 70, the reliability judgment step comprises the steps of:

calculating electric power of each of the data

sequences after the RAKE combination;

averaging the calculation result of the electric power for a previously-determined measuring time; and

selecting the weight sequence having high

5   reliability and the data sequence that is demodulated using the weight sequence so selected based on the averaged electric power.

According to the invention as claimed in claim 74, in the demodulation method as claimed in claim 69 or 70,

10 the reliability judgment step comprises the steps of:

calculating a signal-to-noise ratio of each of the data sequences after the RAKE combination;

averaging the calculation result of the signal-to-noise ratios for a previously-determined measuring

15 time; and

selecting the weight sequence having high reliability and the data sequence that is demodulated using the weight sequence so selected based on the averaged signal-to-noise ratio.

20   According to the invention as claimed in claim 75, in the demodulation method as claimed in claim 69 or 70, the reliability judgment step comprises the steps of:

performing error-correction decoding of the data sequences after the RAKE combination;

25   extracting CRC bits added to the data sequence; decoding the CRC with respect to the data sequence;

detecting the presence or absence of a frame error

based on the decoding result of the CRC;

counting the number of the frame errors in a previously-determined measuring time;

extracting likelihood information that is

5 calculated when performing error-correction d decoding of each of the data sequences;

averaging the extracted likelihood information for a previously-determined measuring time; and

selecting the weight sequence having high

10 reliability and the data sequence that is demodulated using the weight sequence so selected based on the measured number of the frame errors of the plurality of the data sequences and the averaged likelihood information.

According to the invention as claimed in claim 76,

15 in the demodulation method as claimed in either of claim 69 or 70, the reliability judgment step comprises the steps of:

error-correction decoding the data sequences after the RAKE combination;

20 extracting CRC bits added to the data sequence;

decoding the CRC with respect to the data sequence; detecting the presence or absence of a frame error based on the decoding result of the CRC;

counting the number of the frame errors in a

25 previously-determined measuring time;

calculating electric power of each of received data sequences after the RAKE combination;

averaging the calculation result of the electric power for a previously-determined measuring time; and

selecting the weight sequence having high reliability and the data sequence that is demodulated using the weight sequence so selected based on the number of frame errors and the averaged electric power.

According to the invention as claimed in claim 77, in the demodulation method of as claimed in claim 69 or 70, the reliability judgment step comprises the steps of:

error-correction decoding the data sequences after the RAKE combination;

extracting CRC bits added to the data sequence;

decoding the CRC with respect to the data sequence;

detecting the presence or absence of a frame error based on the decoding result of the CRC;

counting the number of the frame errors in a previously-determined measuring time;

calculating a signal-to-noise ratio of each of the data sequences after the RAKE combination;

averaging calculation result of the signal-to-noise ratios for a previously-determined measuring time; and

selecting the weight sequence having a high reliability and the data sequence that is demodulated with the weight sequence so selected based on the number of the frame errors and the averaged signal-to-noise ratio.

According to the invention as claimed in claim 78,

a demodulation method comprises the steps of:

weighting and averaging pilot signals using a plurality of weight sequences to obtain a plurality of channel estimation values;

5   deriving a plurality of demodulated data sequences from a data sequence using the plurality of channel estimation values; and

selecting one output data sequence by making judgment of reliability of the plurality of demodulated

10   data.

According to the invention as claimed in claim 79, in the demodulation method as claimed in claim 78, based on the judgment result of reliability of the plurality of demodulated data sequences, a predetermined number of

15   weight sequences are selected from among the plurality of weight sequences, and after the selection, demodulation through the use of only the selected weight sequences is performed.

According to the invention as claimed in claim 80,

20   in the demodulation method as claimed in any one of claims 69-79, the pilot signals are time multiplexed into a control channel that is parallel multiplexed together with the data channel in which the data sequence is contained.

According to the invention as claimed in claim 81,

25   in the demodulation method as claimed in any one of claims 69-79, the pilot signals are time multiplexed into one channel together with the data sequence.

According to the invention as claimed in claim 82, in the demodulation method as claimed in claim 81, the step of estimating a channel divides the data sequence in the slots of the channel into a plurality of data sequence sections, selects pilot signals appropriate for calculating the channel estimation value of the data of each of the data sequence sections, and calculates a channel estimation value of the data of each of the data sequence sections by weighting and averaging the selected pilot signals.

According to the invention as claimed in claim 83, in the demodulation method as claimed in any one of claims 69-79, the pilot signals are contained in a pilot channel that was parallel multiplexed together with the data channel containing the data sequence.

According to the invention as claimed in claim 84, in the demodulation method as claimed in claim 83, the step of estimating a channel divides the data sequence into a plurality of data sequence sections, selects pilot signals appropriate for calculating the channel estimation value of the data in each of the data sequence sections, and calculates the channel estimation value of the data of each of the data sequence sections by weighting and averaging the selected pilot signals.

With the above configuration, accurate channel estimation can be carried out in the parallel time multiplexing method by subjecting pilot symbols to

weighted averaging to calculate a channel estimated value for data symbols in a data channel.

In addition, accurate channel estimation can be carried out by dividing data symbols within a slot into a plurality of data symbol sections, selecting pilot symbols appropriate for calculation of a channel estimated value for data symbols within each of the data symbol sections, and subjecting the pilot symbols to weighted averaging to calculate the channel estimated value for the data symbols in each data symbol section.

Further, a fading frequency can be decided based on an inner product value of the pilot symbols. In addition, channel estimation optimal for the fading frequency can be realized using a simpler configuration.

In addition, with the above configuration of the present invention, by preparing a plurality of weight sequences ranging from one that becomes effective at a lower movement speed for increasing the averaging time to some degree to one that becomes effective at a higher movement speed for reducing the averaging time to some degree and using all of the plural weight sequences constantly or at fixed time intervals to execute demodulation processing in parallel, a weight sequence effective on various movement speeds can be directly determined from reception quality for use, thereby improving communication quality, reducing the amount of transmission power required, and increasing the

communication capacity.

It is possible to use weighting sequences which are adapted to various movement speeds to perform channel estimation with high accuracy by performing channel estimation using a plurality of weighting factors constantly and selecting data sequence and weighting factors with high reliability by reliability judgment using received data sequence.

Further, by periodically selecting a small number of weight factors and using only the selected weight factors for channel estimation within a fixed period of time, loads on the system can be diminished.

In addition, weight sequences effective on various movement speeds are directly determined from reception quality for use, thereby enabling improvement of communication quality, a reduction in transmission power required, and an increase in communication capacity achieved.

The above and other objects, effects, features, and advantages of the present invention will become more apparent from the following description of embodiments thereof taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a view showing an exemplified configuration of a frame structure of a signal received by a demodulation

device according to a first embodiment of the present invention;

Fig. 2 is a view for use in describing how the demodulation device according to the first embodiment of the present invention estimates channels;

Fig. 3 is a block diagram showing a configuration of a demodulation device according to the first embodiment;

Fig. 4 is a block diagram showing a configuration of the channel estimation unit according to the first embodiment;

Fig. 5 is a block diagram showing a configuration of a fading frequency decision unit according to the first embodiment;

Fig. 6 is a view illustrating an exemplified calculation of the channel estimation value;

Fig. 7 is a view illustrating an operation to calculate the channel estimation value for the respective data symbol segments obtained by means of separating the data symbols in a single slot;

Fig. 8 is a view illustrating calculations of the channel estimation values for the respective data symbol segments that are obtained by means of separating the data symbols in a single slot;

Fig. 9 is a view illustrating calculations of the channel estimation values for the respective data symbol segments that are obtained by means of separating the data symbols in a single slot;

Fig. 10 is a view illustrating calculations of the channel estimation values for the respective data symbol segments that are obtained by means of separating the data symbols in a single slot;

Figs. 11A and 11B are views for use in describing a concept of the fading frequency decision;

Fig. 12 is a graphical representation of a simulated result obtained through a computer, in which the abscissa represents a measurement time and the ordinate represents a measured value with the fading frequency (fDTslot) being used as a parameter;

Fig. 13 is a diagram showing relationship between Figs. 13A and 13B;

Figs. 13A and 13B are block diagrams showing another configuration of the fading frequency decision unit 150 according to the first embodiment;

Fig. 14 is a schematic diagram for explaining an example of the fading frequency decision;

Fig. 15 shows an example of different transmission rates for the data and control channels;

Fig. 16 is a drawing showing a frame configuration example of a signal received by the demodulation device in accordance with the second embodiment of the present invention;

Fig. 17 is a block diagram showing a configuration example of the demodulation device in accordance with the second embodiment;

Fig. 18 is a drawing showing a case where data symbols in one slot are divided into a plurality of data symbol intervals and a channel estimation value is calculated for every data symbol interval;

5   Fig. 19 is a drawing showing a case where data symbols in one slot are divided into a plurality of data symbol intervals and a channel estimation value is calculated for every data symbol interval;

Fig. 20 is a drawing showing a case where data symbols

10   in one slot are divided into a plurality of data symbol intervals and a channel estimation value is calculated for every data symbol interval;

Fig. 21 is a drawing showing a case where data symbols in one slot are divided into a plurality of data symbol

15   intervals and a channel estimation value is calculated for every data symbol interval;

Fig. 22 is a drawing showing a frame configuration example of a signal received by the demodulation device in accordance with the third embodiment of the present

20   invention;

Fig. 23 is a block diagram showing a configuration example of the demodulation device in accordance with the third embodiment;

Fig. 24 is a block diagram showing a configuration

25   example of a channel estimation section in accordance with the third embodiment;

Fig. 25 is a drawing showing a case where data symbols

in a data channel are divided into a plurality of data symbol intervals and a channel estimation value is calculated for every data symbol interval;

Fig. 26 is a drawing showing a case where data symbols in a data channel are divided into a plurality of data symbol intervals and a channel estimation value is calculated for every data symbol interval;

Fig. 27 is a drawing showing a case where data symbols in a data channel are divided into a plurality of data symbol intervals and a channel estimation value is calculated for every data symbol interval;

Figs. 28A and 28B are drawings to explain the concept of determining a fading frequency;

Fig. 29 is a drawing showing an example of channel estimation using pilot signals;

Fig. 30 is a diagram showing relationship between Figs. 30A and 30B;

Figs. 30A and 30B are block diagrams showing the fourth embodiment;

Fig. 31 is a diagram showing relationship between Figs. 31A and 31B;

Figs. 31A and 31B are diagrams showing a modification of the fourth embodiment;

Fig. 32 is a block diagram showing the reliability judgment unit of the fifth embodiment;

Fig. 33 is a block diagram showing the reliability judgment unit of the sixth embodiment;

Fig. 34 is a block diagram showing the reliability judgment unit of the seventh embodiment;

Fig. 35 is a diagram showing relationship between Figs. 35A and 35B;

5   Fig. 35A and 35B are block diagrams showing the reliability judgment unit of the eighth embodiment;

Fig. 36 is a diagram showing relationship between Figs. 36A and 36B;

Fig. 36A and 36B are block diagrams showing the

10   reliability judgment unit of the ninth embodiment;

Fig. 37 is a diagram showing relationship between Figs. 37A and 37B;

Fig. 37A and 37B are block diagrams showing the reliability judgment unit of the tenth embodiment; and

15   Fig. 38 is an illustration showing a dominant conception in the fourth to tenth embodiments.

BEST MODE FOR CARRYING OUT THE INVENTION

The best mode for carrying out the invention will now

20   be described with reference to the accompanying drawings.

(First Embodiment)

Fig. 1 is a view showing an exemplified configuration of a frame structure of a signal received by a demodulation

25   device according to a first embodiment of the present invention. The demodulation device according to the present invention receives and demodulates signals on a

data channel and a control channel that is parallel multiplexed with the data channel. The control channel carries time-multiplexed pilot symbols of a known transmission pattern (of which phase is known, for example,

5   when phase modulation is the primary one). This is called a parallel time multiplexing technique. The received signal (phase and amplitude) at the pilot symbol is used as a reference signal to estimate channel fluctuations of data symbols on the data channel.

10   Fig. 2 is a view for use in describing how the demodulation device according to the first embodiment of the present invention estimates channels. The pilot symbols are used for the channel estimation. More specifically, the pilot symbols (estimated complex fading

15   envelopes) ξ are subjected to coherent combination to take an average value thereof in two or more slots. A weighted sum of the average values ξ' are then taken with, for example, weighting factors α_0, α_1 to thereby calculate a channel estimation value ξ''.

20   Fig. 2 is for the calculation of the channel estimation value $\xi''(n)$ for the data symbols in the nth slot with the channel estimation values of from $\xi'(n-2)$ to $\xi'(n+3)$. The channel estimation value $\xi'(n-2)$ is obtained from the average of the pilot symbols in the

25   (n-2)th pilot blocks that is formed of all pilot symbols in the (n-2)th slot. The channel estimation value $\xi'(n+3)$ is the one for the (n+3)th pilot block. The calculation

in Fig. 2 is carried out as follows:

$$\xi''(n) = \sum_{i=-2}^{3} \alpha_i \cdot \xi'(n+1) \qquad (1)$$

With many pilot symbols belonging to different slots enables highly accurate channel estimation. This is because in an actual mobile propagation environment, interference signals generated due to thermal noise (the noise affects much particularly at cell edges to minimize the transmission power), and by cross-correlation from other users, are added to the desired signal of the current channel, and the channel estimation accuracy is degraded because of the phase and the amplitude of the received signal that vary at every moment due to fading. For the cases where the transmission power is controlled for each slot, the pilot symbols in different slots have different power. However, the channel estimation error due to the power difference is less than the reduction effect by the thermal noise and interference signals caused from using pilot symbols in more slots.

Fig. 3 is a block diagram showing a configuration of a demodulation device according to this embodiment. The demodulation device of this embodiment comprises a data channel matched filter 102, a delay unit 104, a control channel matched filter 106, a channel estimation unit 120, a multiplication unit 108, and a RAKE combiner 110. The demodulation device according to this embodiment is based

on the code division multiple access (CDMA) architecture.
However, it is apparent that the present invention may be
applied to demodulation devices based on other
architectures including the time division multiple access
5   (TDMA) and the frequency division multiple access (FDMA).

Fig. 4 is a block diagram showing a configuration of
the channel estimation unit according to this embodiment.
The channel estimation unit 120 of this embodiment
comprises a slot synchronization detector 122, a pilot
10   symbol averaging unit 124, delay units 126, 128, and 130,
multiplication units 132, 134, and 136, a weighting factor
controller 138, an adder 140, and a fading frequency
decision unit 150. The channel estimation unit 120 may
be implemented in the form of hardware. Alternatively,
15   it may be implemented in the form of software with, for
example, a digital signal processor (DSP).

Fig. 5 is a block diagram showing a configuration of
a fading frequency decision unit according to this
embodiment. The fading frequency decision unit 150 of
20   this embodiment comprises a normalization unit 152, an
inner product calculator 154, a first averaging unit 156,
a second averaging unit 158, and a threshold decision unit
160.

An operation of the demodulation device according to
25   this embodiment is now described with reference to Figs.
3 through 5. The data channel matched filter 102 despreads
a received spread signal on the data channel with a spread

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code replica depending on the timing of the multiple path reception by the individual users. The control channel matched filter 106 despreads a received spread signal on the control channel with the spread code replica depending on the timing of the multiple path reception by the individual users. The slot (pilot block) synchronization detector 122 in the channel estimation unit 120 detects the position of the pilot symbols on the control channel. The pilot symbol averaging unit 124 averages the received channels for the pilot symbols in each pilot block to estimate the channel for the corresponding pilot block, based on the timing information received.

The estimated channel information for each pilot block is supplied to the delay units 126, 128, and 130 to cause them to happen at the same time. Subsequently, with the weighting factor generated by the weighting factor controller 138, the multiplication units 132, 134, and 136, and the adder 140 carries out the weighting averaging (weighting sum) to calculate the channel estimation value.

As shown in, for example, Fig. 2, the channel estimation value for the data symbol in the nth slot may be calculated with the pilot blocks of from the (n-K+1)th pilot block, wherein K is a natural number, to the (n+K)th pilot block (K = 3 in the example in Fig. 2). Alternatively, considering a delay, it may be calculated with the pilot blocks of from (n-K+1)th pilot block to the nth pilot block.

Fig. 6 is a view illustrating an exemplified

calculation of the channel estimation value. In Fig. 6, the channel estimation value for the data symbols in the nth slot is calculated with the pilot blocks of from (n-1)th pilot block to the (n+1)th pilot block. In this event,

5 a ratio of the weighting factors may be $\alpha_{-1}: \alpha_0: \alpha_1 = 0.4:1.0:0.4$. It is preferable that the pilot blocks closer (in time) to the data symbol of which channel estimation value is to be calculated have a larger value of the weighting factor. Such a closer pilot block

10 reflects more the state of a propagation path upon the reception of the data symbol because the propagation path varies at every moment. In the frame configuration in Fig. 6, the pilot blocks (pilot symbols) in the slot occur previously (that is, they are located on the left side in

15 Fig. 6). It is thus possible that a better channel estimation value be obtained with the ratio of the weighting factors of, for example, $\alpha_{-1}: \alpha_0: \alpha_1 = 0.2:1.0:0.6$. As apparent from the above, to determine the weighting factors depending on the location of the pilot

20 symbols in the slot often results in the channel estimation value of higher accuracy.

In Figs. 2 and 6, all pilot symbols in the slot are used for the calculation of the channel estimation value. In addition, the average of the pilot symbols in the pilot

25 block is calculated before taking the weighting average thereof. However, the channel estimation value may be calculated using only some of the pilot symbols in the slot.

The weighting factor may be determined for each pilot symbol to take the weighting average of the pilot symbols. No average calculation is required for the pilot block having only one pilot symbol.

5   While the same channel estimation value is applied to all data symbols in the single slot in Figs. 2 and 6, the data symbols in the slot may be separated into two or more data symbol segments to select a suitable pilot symbol for the calculation of the channel estimation value in each

10   data symbol segment.   In this event, the pilot symbols are averaged with the weighting factors to estimate the channel estimation value for the data symbols in each data symbol segment.

        Fig. 7 is a view illustrating an operation to

15   calculate the channel estimation value for the respective data symbol segments obtained by means of separating the data symbols in a single slot.   In Fig. 7, the channel estimation values are calculated with the pilot blocks of from the (n-1)th pilot block to the (n+1)th pilot block

20   for the data symbol segments (1), (2), and (3).   Likewise, the channel estimation values are calculated with the pilot blocks of from the nth pilot block to the (n+2)th pilot block for the data symbol segments (4), (5), and (6).   The channel estimation values may be calculated with the same

25   weighting factor for the data symbol segments (1), (2), and (3).   Alternatively, these values may be calculated with different weighting factors.   This is also true for

the data symbol segments (4), (5), and (6).

In Fig. 7, the same pilot symbol is selected for the calculation of the channel estimation value for the data symbols in the last data symbol segment (1) in the (n-1)th slot and the calculation of the channel estimation value for the data symbols in the first data symbol segment (2) in the nth slot. The average of these pilot symbols are taken with the weighting factor to obtain the channel estimation value for the data symbols in each data symbol segment.

Figs. 8 through 10 are views illustrating calculations of the channel estimation values for the respective data symbol segments that are obtained by means of separating the data symbols in a single slot. In Figs. 8 through 10, two symbols before and two symbols after the current symbol in the slot on the control channel serve as the pilot symbols. Upon the estimation of the channel, an average value for a certain number of pilot symbols is calculated while shifting the symbol position successively. In Figs. 8 through 10, no average value for the pilot symbols for each pilot block is obtained. Instead, the pilot symbols are directly averaged with the weighting factor.

In Fig. 8, four pilot symbols are used to take the weighting average. The data symbol in a single slot is separated into three segments. In Fig. 9, four pilot symbols are used to take the weighting average. The data

symbol in a single slot is thus separated into four segments.
In Fig. 10, eight pilot symbols are used to take the
weighting average. The data symbol in a single slot is
separated into three segments.

5   In Figs. 8 through 10, the same pilot symbol is
selected for the calculation of the channel estimation
value for the data symbols in the last data symbol segment
in the ith slot, where i is an integer, and the calculation
of the channel estimation value for the data symbols in

10   the first data symbol segment in the (i+1)th slot. The
average of these pilot symbols are taken with the weighting
factor to obtain the channel estimation value for the data
symbols in each data symbol segment.

        In this embodiment, the weighting factors used for
15   taking the weighting average are varied depending on the
fading frequency. The fading frequency decision unit 150
decides the fading frequency based on the average value
for the pilot symbols. The weighting factor controller
138 varies the weighting factor according to the decision

20   result.

        The fading frequency decision unit 150 normalizes the
average values for the pilot symbols in each of the two
slots on the control channel to calculate an inner product
value.

25   Figs. 11A and 11B are views for use in describing a
concept of the fading frequency decision. As shown in Fig.
11A, the channel estimation values in the slots correlates

with each other to a larger degree with the slower
fluctuation of the fading, indicated by a smaller fading
frequency. This provides a larger inner product value.
On the contrary, as shown in Fig. 11B, the channel
estimation values in the slots correlates with each other
to a smaller degree with the faster fluctuation of the
fading, indicated by a larger fading frequency. This
provides a smaller inner product value.

Fig. 12 is a graphical representation of a simulated
result obtained through a computer, in which the abscissa
represents a measurement time and the ordinate represents
a measured value with the fading frequency (fDTslot) being
used as a parameter. In Fig. 12, a threshold value is set
to, for example, 0.3 for the measured value in order to
decide whether the fading frequency is a fast fading of
0.3 or larger. The fading frequency of 0.3 or larger is
decided when the measured value is smaller than the
threshold value.

The normalization unit 152 in the fading frequency
decision unit 150 normalizes the average values for the
pilot symbols in two pilot blocks, that is, two slots on
the control channel. The inner product calculator 154
calculates an inner product value of the average values
for the two normalized pilot symbols.

The demodulation device according to the present
embodiment is a demodulation device which performs the RAKE
combining and it performs the normalization and inner

product calculation for each of the multiple paths used for the RAKE combining as described above. The inner product values obtained from the multiple paths are averaged by the first averaging unit 156. If such

5 averaging is not to be performed among the multiple paths, the first averaging unit 156 is not required.

The average value calculated by the first averaging unit 156 is further averaged among the plurality of slots by the second averaging unit 158 (for example, the inner

10 product values (1), (2), and (3) are averaged in Fig.11A). This may reduce possible influence of thermal noise. If such averaging is not to be performed among the plurality of slots, the second averaging unit 158 is not required.

The threshold decision unit 160 compares the average

15 value calculated by the second averaging unit 158 with the threshold to perform a fading frequency decision. Specifically, it is decided which of the plurality of regions the fading frequency belongs to, by performing a threshold decision with a preset threshold by several steps.

20 The fading frequency decision is performed with the threshold in the present embodiment and however, it may be performed, for example, through calculations.

According to the present embodiment, the fading frequency decision is performed by calculating an inner

25 product of the average value obtained from the pilot symbols of two pilot blocks. These two pilot blocks may be, for example, those for adjacent slots (for example,

the pilot blocks (1) and (2) in Fig. 11A) or those for every other slot (for example, the pilot blocks (1) and (3) in Fig.11A). Alternatively, the fading frequency decision may be performed by calculating an inner product of one

5 pilot symbol and another pilot symbol without any pilot block.

If an inner produce (its average value) of pilot symbols (their average value) (for example, an output of the second averaging section 158 in Fig. 5) is larger than

10 a predetermined value, an average value calculated from the pilot symbols of two slots at a longer interval in the control channel may be subjected to the normalization, the inner product calculation, the inner product averaging among the multiple paths, and the inner product averaging

15 among the plurality of slots as described above and then the averaged inner product value may be compared with a threshold corresponding to such a longer interval to perform the fading frequency decision.

As seen from a graph in Fig. 12 for the inner product

20 value with a fading frequency as a parameter, for higher fading frequencies, it is possible to easily perform the fading frequency decision with a threshold because a difference in frequency results in a relatively large difference in inner products (that is, a higher resolution).

25 On the contrary, for lower fading frequencies, it tends to be difficult to perform the fading frequency decision because such a difference in inner products is relatively

small (that is, a lower resolution).

The resolution for lower fading frequencies can be enhanced by increasing an interval between slots which include pilot symbols used for inner product calculation (inner product measurement interval). For this purpose, if an inner product value with a lower resolution is initially obtained (from pilot symbols of slots at a shorter interval) and the inner product value is larger than a predetermined value (that is, the inner product value is a frequency lower than a predetermined fading frequency), much more accurate decision can be made with respect to a wider range of frequencies from higher fading frequencies to lower fading frequencies by using an inner product value with a higher resolution (from pilot symbols of slots at a longer interval) for the fading frequency decision.

For example, if an inner product value (its average value) of pilot symbols (their average value) of adjacent slots (inner product measurement interval = one-slot interval) (for example, an output of the second averaging unit 158 in Fig. 5) is a value corresponding to a fading frequency equal to or lower than a predetermined frequency, the fading frequency decision can be made with a much higher resolution by performing the threshold decision on another inner product value of pilot symbols at a two-slot interval which is longer than the previous interval by one slot.

If the inner product value for a two-slot interval

is a value corresponding to a fading frequency equal to or lower than a predetermined lower frequency, the fading frequency decision can be made more accurately by using an inner product value of pilot symbols at a three-slot interval which is longer than the previous interval by one slot. Accordingly, the resolution can be enhanced by increasing the inner product measurement interval gradually. (The reason why the inner product measurement interval is varied from a smaller value to a larger value in this way is that the frequency which can be decided for a given inner product measurement interval may become lower as the interval increases.)

It should be appreciated that several inner product calculations with different inner product measurement intervals can be performed in parallel and an appropriate result can be obtained from even such a step-by-step decision as described above for a short time by doing so.

It should be further appreciated that two or more inner product values can be calculated with different inner product measurement intervals to perform the fading frequency decision.

Figs.13A and 13B are block diagrams showing another configuration of the fading frequency decision unit 150 according to the present embodiment. The fading frequency decision unit shown in Figs. 13A and 13B comprises a normalization unit 162, delay units 163-1 and 163-2, inner product calculators 164-1 and 164-2, first averaging units

166-1 and 166-2, second averaging units 168-1 and 168-2, a difference operation unit 169, and a decision unit 170.

In the configuration example of Figs. 13A and 13B, 5 the inner product calculator 164-1 calculates an inner product value for an inner product measurement interval of one slot and the inner product calculator 164-2 calculates an inner product value for that of two slots (that is, every other slot).

10 After the inner product values for these different inner product measurement intervals are averaged among the multiple paths by the first averaging units 166-1 and 166-2 and further averaged among the plurality of slots by the second averaging units 168-1 and 168-2, the difference 15 operation unit 169 calculates a difference between the inner product values for two different inner product measurement intervals (a difference between the inner product value for a one-slot interval and that for a two-slot interval). Then the decision unit 170 performs 20 the fading frequency decision by using the inner product value for a one-slot interval, that for a two-slot interval, and a difference between them.

It should be appreciated that in the example of Figs. 13A and 13B, both the averaging among the multiple paths 25 and the averaging among the plurality of slots are performed but either one or neither of them may be performed.

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Fig. 14 is a schematic diagram for explaining an example of the fading frequency decision. In the example of Fig. 14, the fading frequency decision is made by using a point P_1 (a point where the inner product value for a two-slot interval coincides with the difference (absolute value) first), a point P_2 (a point where the inner product value for a one-slot interval coincides with the difference first), and P_3 (a point where the inner product value for a one-slot interval coincides with that for a two-slot interval first). That is, as the result of such fading frequency decision, any frequency will be decided to be lower than the fading frequency at the point P_1, to be equal to or higher than the fading frequency at the point P_1 and lower than the fading frequency at the point P_2, to be equal to or higher than the fading frequency at the point P_2 and lower than the fading frequency at the point P_3, or to be higher than the fading frequency at the point P_3.

It should be appreciated that such decision may eliminate the need for threshold establishment. It should be further appreciated that it can provide more thorough decision than the case where only one inner product value is calculated for an inner product measurement interval. Therefore, still more inner product values calculated with more different intervals could provide much more thorough decision.

In addition, the fading frequency decision can be made by using only several inner product values without

any difference calculation. In that case, only the point
P_3 in the example of Fig. 14 will be used for decision

Based on thus decided fading frequency, the weighting
factor controller 138 varies the weighting factor.

5   Considering the example of Fig. 6, if the fading frequency
is higher, a larger weighting factor is used for pilot
blocks close (in time) to the data symbols for which channel
estimation values are to be calculated, as compared with
that for a lower fading frequency. That is because, for

10 a higher fading frequency, channel fluctuation for data
symbols for which channel estimation values are to be
calculated is quite different from channel fluctuation for
pilot blocks distant (in time) from these data symbols.
For example, suppose that the weighting factor ratio for

15 a lower fading frequency is $\alpha_{-1}:\alpha_0:\alpha_1=0.2:1.0:0.6$ and the
weighting factor ratio for a higher fading frequency is
$\alpha_{-1}:\alpha_0:\alpha_1=0.05:1.0:0.5$ (on the assumption that the pilot
blocks in the nth slot, those in the (n+1)th slot, and those
in the (n-1)th slot are close, in this order, to data

20 symbols for which channel estimation values are
calculated).

It should be appreciated that, in the present
embodiment, the weighting factor used for calculating a
weighted average varies according to the fading frequency

25 but a fixed weighting factor may be used.

The channel estimation values (the output of the
adder 140) calculated as described above are used to

compensate for channel fluctuation (fading fluctuation) of despread data symbols timed by the delay unit 104. Specifically, the despread data symbols are multiplied by the complex conjugates of the channel estimation values

5   to compensate for such channel fluctuation. Then the RAKE combiner 110 carries out coherent combining of the compensated signals.

It should be appreciated that, in the present embodiment, the data channel has the same transmission rate

10 as that of the control channel but these two channels may have different transmission rates.

Fig. 15 shows an example of different transmission rates for the data and control channels. In the example of Fig. 15, the control channel has half the transmission

15 rate of the data channel. Even if such different transmission rates are used for these channels, channel estimation values can be obtained from pilot symbols.

(Second Embodiment)

20   Fig. 16 is a drawing showing a frame configuration example of a signal received by the demodulation device in accordance with the second embodiment of the present invention. The demodulation device in accordance with the present embodiment receives and demodulates a signal of

25 a channel in which data symbols and pilot symbols are time multiplexed (time multiplexing system). A signal received by this pilot symbol section (phase, amplitude)

is used as a reference signal to estimate channel
fluctuations of data symbols. Pilot symbols are inserted
into data symbols at fixed intervals. The channel
estimation method in the demodulation device in accordance
5   with the present embodiment is the same as the channel
estimation method in the demodulation device in accordance
with the first embodiment of the present invention.

Fig. 17 is a block diagram showing a configuration
example of the demodulation device in accordance with the
10   present embodiment. The demodulation device in
accordance with the present embodiment comprises a matched
filter 202, a delay unit 204, a channel estimation unit
220, a multiplication unit 208 and a RAKE combiner 210.
Although the demodulation device in the present embodiment
15   is also compliant with a CDMA system, it is also possible
to apply the present invention to demodulation devices
compliant with other systems (for example, TDMA system and
FDMA system). The demodulation device in the present
embodiment carries out multiple access transmission by
20   spreading a signal into a wideband signal using a spreading
code faster than an information rate.

The configuration example of the channel estimation
unit 220 in accordance with the present embodiment is the
same as the configuration example of the channel estimation
25   unit 120 in accordance with the first embodiment of the
present invention shown in Fig. 4. Slot synchronization
detector 122 detects pilot symbol locations in a channel

in which data symbols and pilot symbols are time multiplexed. The configuration example of the fading frequency decision unit of the present embodiment is also the same as the configuration example of the fading

5   frequency decision unit 150 of the first embodiment of the present invention shown in Fig. 5 (it can also be configured as shown in Fig. 13A and Fig. 13B).

The operation of the demodulation device of the present embodiment is also the same as the operation of

10 the demodulation device of the first embodiment of the present invention.

Fig. 18 is a drawing showing a case where data symbols in one slot are divided into a plurality of data symbol intervals and a channel estimation value is calculated for

15 every data symbol interval. In the example of Fig. 18, for data symbol intervals (1) and (2), a channel estimation value is calculated using the (n-1)th pilot block to the (n+1)th pilot block, and for data symbol intervals (3) and (4), a channel estimation value is calculated using the

20 nth pilot block to the (n+2)th pilot block. The channel estimation values for data symbol intervals (1) and (2) can be calculated using a same weighting factor or using different weighting factors. The same applies to data symbol intervals (3) and (4).

25 Moreover, in the example of Fig. 18, in calculating a channel estimation value of data symbols in the last data symbol interval (1) of the (n-1)th slot and calculating

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a channel estimation value of data symbols in the first data symbol interval (2) of the nth slot, a same pilot symbol is selected and the pilot symbol is weighted and averaged to calculate a channel estimation value of data
5   symbols during each data symbol interval.

Fig. 19 to Fig. 21 also show cases where data symbols in one slot are divided into a plurality of data symbol intervals and a channel estimation value is calculated for every data symbol interval. In the examples of Fig. 19
10   to Fig. 21, two symbols before and two symbols after a control channel slot are pilot symbols. Furthermore, in channel estimation, an average value for a certain number of pilot symbols is calculated while moving the symbol position successively. In the examples of Fig. 19 to Fig.
15   21, pilot symbols are directly weighted and averaged without calculating an average value of pilot symbols for each pilot block.

In the example of Fig. 19, four pilot symbols are used for weighting and averaging and data symbols in one slot
20   are divided into three intervals. In the example of Fig. 20, four pilot symbols are used for weighting and averaging and data symbols in one slot are divided into five intervals. In the example of Fig. 21, eight pilot symbols are used for weighting and averaging and data symbols in one slot
25   are divided into three intervals.

In the examples of Fig. 19 to Fig. 21, in calculating a channel estimation value of data symbols during the last

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data symbol interval of the ith (i: an integer) slot and calculating a channel estimation value of data symbols during the first data symbol interval of the (i+1)th slot, a same pilot symbol is selected and the pilot symbol is

5   weighted and averaged to calculate a channel estimation value of data symbols during each data symbol interval.

In the present embodiment, weighting factors used for weighting and averaging are changed according to the fading frequency. However, it is also possible to use a fixed

10   weighting factor.

Data symbol channel fluctuations (fading fluctuations) after despreading whose timing is determined by the delay section 204 are compensated using the channel estimation value obtained by the channel estimation

15   section 220. More specifically, channel fluctuations are compensated by multiplying the despread data symbols by a complex conjugate of the channel estimation value. Then, the compensated signals are combined in-phase by the RAKE combiner 210.

20   In the present embodiment, data symbols and pilot symbols in a channel have a same transmission rate, but data symbols and pilot symbols in the channel can also have different transmission rates.

25   (Third Embodiment)

The above concept can also be applied to a parallel system.

Fig. 22 is a drawing showing a frame configuration example of a signal received by the demodulation device in accordance with the third embodiment of the present invention. The demodulation device in accordance with the present embodiment receives and demodulates signals of a data channel and a pilot channel, which is parallel multiplexed with the data channel (parallel system). A received signal (phase, amplitude) of the pilot symbol of this pilot channel is used as a reference signal to estimate channel fluctuations of data symbols in the data channel. In the parallel system, unlike the parallel time multiplexing system or time multiplexing system that transmit/receive pilot symbols using some slots, pilot symbols are transmitted/received consecutively, and therefore the concept of a "slot" is not so important. For this reason, slots are not indicated in Fig. 22.

The channel estimation method in the demodulation device in accordance with the present embodiment is basically the same as the channel estimation method by the demodulation device in accordance with the first and second embodiments, but specific examples will be explained below.

Fig. 23 is a block diagram showing a configuration example of the demodulation device in accordance with the present embodiment. The demodulation device in accordance with the present embodiment comprises a data channel matched filter 302, a delay unit 304, a pilot

channel matched filter 306, a channel estimation unit 320, a multiplication unit 308 and a RAKE combiner 310. Although the demodulation device in the present embodiment is also compliant with a CDMA system, it is also possible

5   to apply the present invention to demodulation devices compliant with other systems (for example, TDMA system and FDMA system).

Fig. 24 is a block diagram showing a configuration example of a channel estimation section in accordance with

10   the present embodiment. The channel estimation unit 320 of the present embodiment comprises a pilot symbol averaging unit 324, delay units 326, 328, 330, etc., multiplication units 332, 334, 336, etc., a weighting factor controller 338, an adder 340 and a fading frequency

15   decision unit 350. The configuration example of the fading frequency decision unit (fading frequency decision unit 350) of the present embodiment is the same as the configuration example of the fading frequency decision unit 150 of the first embodiment of the present invention

20   shown in Fig. 5 (can also be configured as shown in Fig. 13A and Fig. 13B).

The operation of the demodulation device of the present embodiment is also basically the same as the operation of the demodulation device of the first and

25   second embodiments.

Fig. 25 is a drawing showing a case where data symbols in a data channel are divided into a plurality of data

symbol intervals and a channel estimation value is
calculated for every data symbol interval.   In the example
of Fig. 25, data symbols are divided into intervals, with
each interval containing 3 symbols, and a channel

5   estimation value is calculated using the corresponding
pilot symbol interval (3-symbol configuration) on the time
scale and pilot symbol intervals before and after.   More
specifically, channel estimation value ξ'' is calculated
by weighting channel estimation value $\xi'(0)$ obtained from

10   averaging the 3 symbols in the pilot symbol interval
corresponding on the time scale, channel estimation values
$\xi'(-1)$ and $\xi'(1)$ obtained from averaging during the pilot
symbol intervals before and after, with α_0, α_{-1} and α_1,
respectively and averaging them.

15   Fig. 26 and Fig. 27 are also drawings showing cases
where data symbols in a data channel are divided into a
plurality of data symbol intervals (one interval for one
symbol) and a channel estimation value is calculated for
every data symbol interval.   In channel estimation, an

20   average value for a certain number of pilot symbols is
calculated while moving the symbol position successively.
In the examples of Fig. 26 and Fig. 27, pilot symbols are
directly weighted and averaged without weighting and
averaging after obtaining an average value of pilot symbols

25   as in the example of Fig. 25.

In the example of Fig. 26, four pilot symbols are used
for weighting and averaging and a pilot symbol used for

weighting and averaging is changed for every one data symbol. In the example of Fig. 27, four pilot symbols are used for weighting and averaging and a pilot symbol used for weighting and averaging is changed for every two data

5 symbols.

In the present embodiment, the weighting factor used for weighting and averaging is changed according to a fading frequency. However, it is also possible to use a fixed weighting factor.

10 Fig. 28A and Fig. 28B are drawings to explain the concept of determining a fading frequency. The fading frequency determining method of the present embodiment is basically the same as the fading frequency determining method of the first and second embodiments. In the first

15 and second embodiments, an average value of pilot symbols of each of two slots is used. In the present embodiment, an average value of pilot symbols of each of two pilot channel intervals is used. The two intervals can be discontinuous or continuous (discontinuous in the case of

20 Fig. 28). The number of pilot symbols included in one interval can be one or two or more.

In the present embodiment, as in the case of the first and second embodiments, if a calculated inner product value is larger than a predetermined value, it is possible to

25 calculate the inner product value by increasing the interval (inner product measurement interval) at which a pilot symbol used for calculation of the inner product

value is inserted. It is also possible to calculate two
or more inner products by changing the inner product
measurement interval and decides the fading frequency
using those inner product values.

5   Channel fluctuations (fading fluctuations) after
despreading whose timing is determined by the delay unit
304 are compensated using the channel estimation value
obtained from the channel estimation unit 320. More
specifically, channel fluctuations are compensated by
10   multiplying the despread data symbols by a complex
conjugate of the channel estimation value. Then, the
compensated signals are combined in-phase by the RAKE
combiner 310.

      In the present embodiment, as in the case of the first
15   embodiment, data channels and pilot channels can also have
different transmission rates.

(Fourth Embodiment)

      At first, an averaging method of a pilot signal in
20   channel estimation to be used in the fourth to tenth
embodiment of the present invention will be described with
reference to Fig. 29. As shown in Fig. 29, from a
communication counterpart station, a known pilot symbol
of a transmission pattern (phase when a primary modulation
25   is phase modulation) is transmitted together with an
information data symbol. At this time, the pilot symbol
is not transmitted continuously as shown in Fig. 29 but

also intermittently. Namely, an insertion method of the pilot symbol may be a parallel time multiplexing system (Fig. 1), time multiplexing system (Fig. 16) and a parallel system (Fig. 22).

5   In order to perform estimation of phase fluctuation of a propagation path to perform compensation (phase correction) of a communication channel, a channel estimation value is derived by averaging the pilot signal of preceding and following zone of a reception data to be corrected the phase. In the example of Fig. 29, in order to derive a channel vector of N(th) symbol of the communication channel, preceding and following pilot signals are averaged using a weighting sequences a (here a = {a(k)|k = ... -1, 0, 1, ...}

15   It should be noted that when averaging is performed using the weighting sequences, averaging is performed using the weighting sequences after simple averaging per arbitrary block greater than or equal to a chip unit.

       In the fourth to tenth embodiment which will be described hereinafter in detail, in a demodulation device according to the direct sequence CDMA system, the channel estimation value is derived by weighted averaging of the pilot signal using a plurality of predetermined weighting sequences. Then, using the derived channel estimation value, the reception data is demodulated. By making judgment for credibility of a plurality of demodulation data, data of the highest quality is selected.

On the other hand, it is also possible to select some of weighting sequences on the basis of result of judgment of credibility of the demodulated data sequence in terms of a certain given period. In this case, demodulation is performed only by the weighting sequences selected, subsequently.

(Construction of the Fourth Embodiment)

Figs. 30A and 30B are block diagrams showing the fourth embodiment. In these drawings, 1 denotes a despreading unit, 2(including 2-1 to 2-N) denote channel estimation units, 3 (including 3-1 to 3-N) denotes multipliers, 4(including 4-1 to 4-N) denote RAKE combiners, 5(including 5-1 to 5-N) denote FEC decoders, 6 (including 6-1 to 6-N) denote CRC decoders, 7 (including 7-1 to 7-N) denote frame error number counters, 8A denotes a reliability comparator, 9 denotes a reliability judgment unit and 10 denotes a first switch.

(Operation of Fourth Embodiment)

Next, operation of the fourth embodiment of the CDMA demodulation device shown in Figs. 30A and 30B will be explained.

At first, a received spread signal is input to the despreader 1. The input reception spread data sequence is despread using a spread code replica depending upon a timing of multiple path.

In the channel estimation units 2, N (N $\geqq$ 2) in number of the weighting sequences for performing averaging of the

pilot signals are provided. The pilot signals are averaged with respective weighting sequences in parallel to derive the channel estimation values.

In the multiplier 3, phase correction is performed by multiplying the despread data sequence of the communication channel with complex conjugate of respective channel estimation values.

Next, in the RAKE combiners 4, the signals after phase correction is coherent combined in all of RAKE fingers and input to the reliability judgment unit 9.

In the reliability judgment unit 9, at first, decoding of the error correction code is performed in the FEC decoders 5 to output N in number of decoded data of the weighting coefficient from #1 to #N.

In the CRC decoder 6, decoding of CRC is performed using the extracted CRC bit among decoded data sequence to make judgment whether frame error is present or not to input the result of judgment to the frame error number counter 7.

In the frame error number counter 7, counting of the frame error number present during a period of predetermined number of frames is performed to input the counted number to the reliability comparator 8.

In the reliability comparing and judgment unit 8A, the data sequence having the least frame error number is selected from the frame error information of N sequence to output the foregoing data by switching the first switch

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10 to the desired sequence.

(Effect of Fourth Embodiment)

As explained above, by the fourth embodiment, channel estimation using a plurality of weighting coefficients is constantly performed and weighting coefficients corresponding to various motion speeds are used simultaneously by selecting data having high reliability through reliability judgment using the reception data sequence to permit channel estimation at high precision. On the other hand, using the result of CRC decoding, judgment to lower of the frame error ratio can be performed by selecting the weighting sequences having frame error.

(Modification of Fourth Embodiment)

In the explanation set forth above, while channel estimation to CRC decoding is performed constantly using N in number of weighting sequences, load of the system can be reduced by the following modification.

A modification of the fourth embodiment is shown in Figs. 31A and 31B.

In Figs. 31A and 31B, the same portions to those in the fourth embodiment shown in Figs. 30A and 30B are identified by the same reference numerals. 11 denote second switches.

At every given period, concerning data sequence of the predetermined number of frames, all of the second switches 11 are turned ON to perform operation of the foregoing fourth embodiment is performed in N sequences.

Also, in the reliability judgment unit 9, N' (here N': natural number, $1 \leqq N' < N$) in number of weighting sequences having high reliability in the foregoing frame number are selected. After judgment of reliability, concerning remaining data sequence until performing reliability judgment again in the foregoing time interval, only second switches 11 of the selected weighting sequences are turned ON, and other weighting sequences are turned OFF. Thus, similar operation to the foregoing fourth embodiment is performed in N' sequences using selected N' in number of weighting sequences.

It should be noted that Figs. 31A and 31B show example in which two sequences of weighting sequences #1 and #2 are selected (N' = 2) and only two sequences are in operating condition.

(Fifth Embodiment)
(Construction of Fifth Embodiment)

Fig. 32 is a block diagram showing the reliability judgment unit of this fifth embodiment. Other functional blocks correspond to the fourth embodiment and will be omitted from disclosure. The same portions to the fourth embodiment shown in Figs. 30A and 30B are identified by the same reference numerals. 12 (12-1 to 12-N) denote likelihood averaging units.

(Operation of Fifth Embodiment)

Next, operation of the fifth embodiment of the

reliability judgment unit will be explained. Operation
of other functional block corresponds to those of the
fourth embodiment and explanation thereof is omitted.

The RAKE combined signal is input to the FEC decoder
5. In the FEC decoder 5, decoding of the error correction
code is performed to output decoding data from the
weighting sequence #1 to #N, and in conjunction therewith,
likelihood information calculated upon error correction
is input to the likelihood averaging unit 12.

In the likelihood averaging unit 12, input likelihood
is averaged over the predetermined number of frames, Y
frames (here, Y: natural number, $Y \geqq 1$) to input to the
reliability comparator 8. In the reliability comparator
8, from the likelihood information of the N sequences, the
data sequence having the highest reliability is selected
as information output.

(Effect of Fifth Embodiment)

As explained above, according to the fifth embodiment,
by using the likelihood information calculated upon error
correction decoding, judgment reflecting communication
quality (bit error ratio or the like) can be performed.

(Modification 1 of Fifth Embodiment)

In the foregoing explanation, while channel
estimation to CRC decoding is performed constantly using
N in number of weighting sequences, load of the system can
be reduced by the following modification.

The modification of the fifth embodiment can be

constructed by replacing the reliability judgment unit of the modification of the fourth embodiment shown in Figs. 31A and 31B with the fifth embodiment shown in Fig. 32.

5 At every given period, concerning data sequence of the predetermined number of frames, all of the second switches 11 are turned ON to perform operation of the foregoing fourth embodiment is performed in N sequences. Also, in the reliability judgment unit, N' (here N': natural number, $1 \leqq N' < N$) in number of weighting sequences 10 having high reliability in the foregoing frame number are selected. After judgment of reliability, concerning remaining data sequence until performing reliability judgment again in the foregoing time interval, only second switches 11 of the selected weighting sequences are turned 15 ON, and other weighting sequences are turned OFF. Thus, similar operation to the foregoing fourth embodiment is performed in N' sequences using selected N' in number of weighting sequences.

(Modification 2 of Fifth Embodiment)

20 In the foregoing explanation, in the likelihood averaging unit 12, in addition to a method of simple averaging of the likelihood to predetermined number of frames, Y frames (here, Y: natural number, $Y \geqq 1$), weighted averaging, method for selecting the minimum value and 25 method for selecting the maximum value may be taken.

(Sixth Embodiment)

(Construction of Sixth Embodiment)

Fig. 33 is a block diagram showing the reliability judgment unit of this sixth embodiment. Other functional blocks correspond to the fourth embodiment and will be omitted from disclosure. The same portions to the fourth embodiment shown in Figs. 30A and 30B are identified by the same reference numerals. 13 (including 13-1 to 13-N) denote power calculators.

(Operation of Sixth Embodiment)

Next, operation of the sixth embodiment of the reliability judgment unit will be explained.
Operation of other functional block corresponds to those of the fourth embodiment and explanation thereof is omitted.

The RAKE combined signals are input to the power calculators 13. In the power calculators 13, powers of the signals after RAKE combination in N sequences are calculated and averaged over the predetermined period.

The averaged power calculated values are input to the reliability comparator. In the reliability comparing and judgment unit 8, the data sequence having the highest reliability is selected from the power calculated values in N sequences to input to the FEC decoder 5. In the error correction decoding is performed in the FEC decoder 5 and is output as information output.

(Effect of Sixth Embodiment)

As explained above, in the shown sixth embodiment,

by using the reception power after RAKE combination in reliability judgment, judgment to make the reception power greater can be performed. Thus, communication quality (frame error ratio or the like) can be improved, and also,

5 since judgment of reliability can be made by performing FEC decoding, reduction of the load of the system becomes possible.

(Modification of Sixth Embodiment)

In the foregoing explanation, channel estimation and

10 power calculation is performed constantly using N in number of weighting sequences, load of the system can be reduced by the following modification.

The modification of the sixth embodiment can be constructed by replacing the reliability judgment unit of

15 the modification of the fourth embodiment shown in Figs. 31A and 31B with the sixth embodiment shown in Fig. 33.

At every given period, concerning data sequence of the predetermined number of frames, all of the second switches 11 are turned ON to perform operation of the

20 foregoing fourth embodiment is performed in N sequences. Also, in the reliability judgment unit, N' (here N': natural number, $1 \leqq N' < N$) in number of weighting sequences having high reliability in the foregoing frame number are selected. After judgment of reliability, concerning

25 remaining data sequence until performing reliability judgment again in the foregoing time interval, only second switches 11 of the selected weighting sequences are turned

ON, and other weighting sequences are turned OFF. Thus, similar operation to the foregoing fourth embodiment is performed in N' sequences using selected N' in number of weighting sequences.

5

(Seventh Embodiment)

(Construction of Seventh Embodiment)

Fig. 34 is a block diagram showing the reliability judgment unit of this seventh embodiment. Other

10 functional blocks correspond to the fourth embodiment and will be omitted from disclosure. The same portions to the fourth embodiment shown in Figs. 30A and 30B are identified by the same reference numerals. 14 (including 14-1 to 14-N) denote SN ratio calculators.

15 (Operation of Seventh Embodiment)

Next, operation of the seventh embodiment of the reliability judgment unit will be explained. Operation of other functional block corresponds to those of the fourth embodiment and explanation thereof is omitted.

20 The RAKE combined signals are input to the SN ratio calculators 12. In the SN ratio calculators 14, SN ratios of the signals after RAKE combination in N sequences are calculated and are averaged over the predetermined period. The averaged SN ratio calculated values are input to the

25 reliability comparator 8.

In the reliability comparator 8, the data sequence having highest reliability is selected among SN ratio

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calculated values in N sequences to be input to the FEC decoder 5. Error correction decoding is performed in the FEC decoder 5 to output as the information output.

(Effect of Seventh Embodiment)

As explained above, in the shown seventh embodiment, by using the SN ratio after RAKE combination in reliability judgment, judgment to make the SN ratio greater can be performed. Thus, communication quality (frame error ratio or the like) can be improved, and also, since judgment of reliability can be made by performing FEC decoding, reduction of the load of the system becomes possible.

(Modification of Seventh Embodiment)

In the foregoing explanation, channel estimation and SN ratio calculation is performed constantly using N in number of weighting sequences, load of the system can be reduced by the following modification.

The modification of the seventh embodiment can be constructed by replacing the reliability judgment unit of the modification of the fourth embodiment shown in Figs. 31A and 31B with the seventh embodiment shown in Fig. 34.

At every given period, concerning data sequence of the predetermined number of frames, all of the second switches 11 are turned ON to perform operation of the foregoing fourth embodiment is performed in N sequences. Also, in the reliability judgment unit, N' (here N': natural number, $1 \leqq N' < N$) in number of weighting sequences having high reliability in the foregoing frame number are

selected. After judgment of reliability, concerning
remaining data sequence until performing reliability
judgment again in the foregoing time interval, only second
switches 11 of the selected weighting sequences are turned

5   ON, and other weighting sequences are turned OFF. Thus,
similar operation to the foregoing fourth embodiment is
performed in N' sequences using selected N' in number of
weighting sequences.

10   (Eighth Embodiment)

(Construction of Eighth Embodiment)

Figs. 35A and 35B are block diagrams showing the
reliability judgment unit of this Eighth embodiment. The
functional blocks other than the reliability judgment unit

15   correspond to the fourth embodiment and will be omitted
from disclosure. The same portions to the fourth
embodiment shown in Figs. 30A and 30B are identified by
the same reference numerals.

(Operation of Eighth Embodiment)

20   Next, operation of the eighth embodiment of the
reliability judgment unit will be explained. Operation
of other functional block corresponds to those of the
fourth embodiment and explanation thereof is omitted.

The RAKE combined signals are input to the FEC

25   decoders 5. Decoding of the error correction code is
performed in the FEC decoders 5 to output decoded data with
the weighting coefficients #1 to #N, and also, likelihood

information calculated upon error correction is input to the likelihood averaging unit 12.

In the likelihood averaging unit 12, input likelihood is averaged over the predetermined number of frames, Y frames (here, Y: natural number, Y $\geqq$ 1) to input to the reliability comparator 8.

On the other hand, in the CRC decoder 6, decoding of CRC is performed using CRC bit extracted from the data sequences decoded by the FEC decoder 5 to make judgment whether the frame error is present or not to input the result of judgment to the frame error number calculator 7.

In the frame error number calculator 7, counting of the frame error number present in the predetermined Y2 frame (here Y2: natural number, Y2 $\geqq$ 1) is performed to input the counted number to the reliability comparator 8.

In the reliability comparator 8, the data sequence having the highest reliability is selected as the information output based on the likelihood information input from the likelihood averaging unit 12, among the sequences having the lest frame error number based on the frame error information of N sequences output from the frame error number calculator 7.

(Effect of Eighth Embodiment)

As explained above, in the shown Eighth embodiment, by using likelihood information calculated upon error correction decoding in addition to the counted frame error

number from the result of CRC decoding, in reliability judgment, the judgment factors are mutually combined to permit strict reliability judgment.

(Modification 1 of Eighth Embodiment)

5   In the foregoing explanation, channel estimation and CRC decoding is performed constantly using N in number of weighting sequences, load of the system can be reduced by the following modification.

       The modification of the Eighth embodiment can be 10 constructed by replacing the reliability judgment unit of the modification of the fourth embodiment shown in Figs. 31A and 31B with the eighth embodiment shown in Figs. 35A and 35B.

       At every given period, concerning data sequence of 15 the predetermined number of frames, all of the second switches 11 are turned ON to perform operation of the foregoing fourth embodiment is performed in N sequences. Also, in the reliability judgment unit, N' (here N': natural number, $1 \leq N' < N$) in number of weighting sequences 20 having high reliability in the foregoing frame number are selected. After judgment of reliability, concerning remaining data sequence until performing reliability judgment again in the foregoing time interval, only second switches 11 of the selected weighting sequences are turned 25 ON, and other weighting sequences are turned OFF. Thus, similar operation to the foregoing fourth embodiment is performed in N' sequences using selected N' in number of

weighting sequences.

(Modification 2 of Eighth Embodiment)

In the foregoing explanation, in the likelihood averaging unit 12, in addition to a method of simple averaging of the likelihood to predetermined number of frames, Y frames (here, Y1: natural number, $Y1 \geqq 1$), weighted averaging, method for selecting the minimum value and method for selecting the maximum value may be taken.

(Ninth Embodiment)

(Construction of Ninth Embodiment)

Figs. 36A and 36B are block diagrams showing the reliability judgment unit of this ninth embodiment. The functional blocks other than the reliability judgment unit correspond to the fourth embodiment and will be omitted from disclosure. The same portions to the fourth embodiment shown in Figs. 31A and 31B are identified by the same reference numerals.

(Operation of Ninth Embodiment)

Next, operation of the ninth embodiment of the reliability judgment unit will be explained. Operation of other functional block corresponds to those of the fourth embodiment and explanation thereof is omitted.

The RAKE combined signals are input to the power calculator 13. In the power calculator 13, the power of the signals after RAKE combination in N sequences are calculated. After averaging over the predetermined

period, the calculated value is input to the reliability comparator 8.

On the other hand, in the FEC decoders 5, decoding of the error correction code is performed to output decoded data with the weighting coefficients #1 to #N, and, in the CRC decoder 6, decoding of CRC is performed using CRC bit extracted from the data sequences decoded by the FEC decoder 5 to make judgment whether the frame error is present or not to input the result of judgment to the frame error number calculator 7.

In the frame error number calculator 7, counting of the frame error number present in the predetermined Y frame (here Y2: natural number, $Y \geqq 1$) is performed to input the counted number to the reliability comparator 8.

In the reliability comparator 8, the data sequence having the highest reliability is selected as the information output based on the power calculated value, among the sequences having the lest frame error number based on the frame error information of N sequences output from the frame error number calculator 7.

(Effect of Ninth Embodiment)

As explained above, in the shown ninth embodiment, by using the received power after RAKE combination in addition to the counted frame error number from the result of CRC decoding, in reliability judgment, the judgment factors are mutually combined to permit strict reliability judgment.

(Modification 1 of Ninth Embodiment)

In the foregoing explanation, channel estimation and CRC decoding is performed constantly using N in number of weighting sequences, load of the system can be reduced by the following modification.

The modification of the ninth embodiment can be constructed by replacing the reliability judgment unit of the modification of the fourth embodiment shown in Figs. 31A and 31B with the ninth embodiment shown in Figs. 36A and 36B.

At every given period, concerning data sequence of the predetermined number of frames, all of the second switches 11 are turned ON to perform operation of the foregoing fourth embodiment is performed in N sequences. Also, in the reliability judgment unit, N' (here N': natural number, $1 \leq N' < N$) in number of weighting sequences having high reliability in the foregoing frame number are selected. After judgment of reliability, concerning remaining data sequence until performing reliability judgment again in the foregoing time interval, only second switches 11 of the selected weighting sequences are turned ON, and other weighting sequences are turned OFF. Thus, similar operation to the foregoing fourth embodiment is performed in N' sequences using selected N' in number of weighting sequences.

(Tenth Embodiment)

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(Construction of Tenth Embodiment)

Figs. 37A and 37B are block diagrams showing the reliability judgment unit of this tenth embodiment. The functional blocks other than the reliability judgment unit

5 correspond to the fourth embodiment and will be omitted from disclosure. The same portions to the fourth embodiment shown in Figs. 31A and 31B are identified by the same reference numerals.

(Operation of Tenth Embodiment)

10 Next, operation of the tenth embodiment of the reliability judgment unit will be explained. Operation of other functional block corresponds to those of the fourth embodiment and explanation thereof is omitted.

The RAKE combined signals are input to the SN ratio

15 calculators 12. In the SN ratio calculators 14, SN ratios of the signals after RAKE combination in N sequences are calculated and are averaged over the predetermined period. The averaged SN radio calculated values are input to the reliability comparator 8.

20 On the other hand, in the FEC decoders 5, decoding of the error correction code is performed to output decoded data with the weighting coefficients #1 to #N, and, in the CRC decoder 6, decoding of CRC is performed using CRC bit extracted from the data sequences decoded by the FEC

25 decoder 5 to make judgment whether the frame error is present or not to input the result of judgment to the frame error number calculator 7.

In the frame error number calculator 7, counting of the frame error number present in the predetermined Y frame (here Y2: natural number, $Y \geqq 1$) is performed to input the counted number to the reliability comparator 8.

In the reliability comparator 8, the data sequence having the highest reliability is selected as the information output based on the SN ratio calculated value, among the sequences having the least frame error number based on the frame error information of N sequences output from the frame error number calculator 7.

(Effect of Tenth Embodiment)

As explained above, in the shown tenth embodiment, by using the SN ratio after RAKE combination in addition to the counted frame error number from the result of CRC decoding, in reliability judgment, the judgment factors are mutually combined to permit strict reliability judgment.

(Modification 1 of Tenth Embodiment)

In the foregoing explanation, channel estimation and CRC decoding is performed constantly using N in number of weighting sequences, load of the system can be reduced by the following modification.

The modification of the tenth embodiment can be constructed by replacing the reliability judgment unit of the modification of the fourth embodiment shown in Figs. 31A and 31B with the tenth embodiment shown in Figs. 37A

and 37B.

At every given period, concerning data sequence of
the predetermined number of frames, all of the second
switches 11 are turned ON to perform operation of the
foregoing fourth embodiment is performed in N sequences.
Also, in the reliability judgment unit, N' (here N':
natural number, $1 \leqq N' < N$) in number of weighting sequences
having high reliability in the foregoing frame number are
selected. After judgment of reliability, concerning
remaining data sequence until performing reliability
judgment again in the foregoing time interval, only second
switches 11 of the selected weighting sequences are turned
ON, and other weighting sequences are turned OFF. Thus,
similar operation to the foregoing fourth embodiment is
performed in N' sequences using selected N' in number of
weighting sequences.

(Summarization of Fourth to Tenth Embodiments)

Fig. 38 is an illustration showing a dominant
conception in the fourth to tenth embodiments explained
above. In Fig. 38, 30 denotes despreader, 40 (including
40-1 to 40-N) denote receiving unit, 50 (including 50-1
to 50-N) denote quality measuring units, 60 denotes a
quality comparing and judging unit, and 70 denotes an
output switch.

Namely, in the demodulation device according to the
direct sequence CDMA system, weighted averaging of the
pilot signal using predetermined plurality of weighting

sequences is performed to derive the channel estimation values. Then, using the derived channel estimation values, the received data is demodulated (40) to make judgment of reliability of a plurality of demodulation data to select

5   one of output data of the best quality (50, 60, 70).

On the other hand, concerning a certain given period, it is possible to select some of the weighting sequences on the basis of the result of judgment of the reliability of the demodulated data sequences. In this case,

10   subsequently, demodulation is performed only by the selected weighting sequences.

It should be noted that, as the channel estimation unit 2 of the fourth to the tenth embodiments, the channel estimation units 120, 220 and 320 in the first to third

15   embodiments may also be used.

As described above, according to the present invention, accurate channel estimation can be carried out in the parallel time multiplexing method by subjecting

20   pilot symbols to weighted averaging to calculate a channel estimated value for data symbols in a data channel.

In addition, accurate channel estimation can be carried out by dividing data symbols within a slot into a plurality of data symbol sections, selecting pilot

25   symbols appropriate for calculation of a channel estimated value for data symbols within each of the data symbol sections, and subjecting the pilot symbols to weighted

averaging to calculate the channel estimated value for the data symbols in each data symbol section.

Further, a fading frequency can be decided based on an inner product value of the pilot symbols. In addition, channel estimation optimal for the fading frequency can be realized using a simpler configuration.

Once accurate channel estimation has been achieved, the absolute synchronous detection method can be used to reduce the SNIR required to obtain a required reception quality (reception error rate). As a result, the required transmission power can be diminished to increase the capacity for system subscribers.

The results of decision obtained by the fading frequency decision unit can be used not only for setting the weight factor for channel estimation but also for operation switching or parameter setting for various individual techniques the performance (transmission characteristic) of which is affected by the movement speed of a mobile terminal (portable terminal), for example, switching between an operative and inoperative states for transmission power control or for transmission diversity.

In addition, according to the present invention, a weight sequence effective on a movement speed is directly determined from reception quality for use, thereby enabling improvement of communication quality, a reduction in transmission power required, and an increase in communication capacity achieved. More specifically, the

present invention can provide the following effects:

(1) Since weight sequences suitable for various movement speeds can be sequentially selected, accurate channel estimation is possible. This enables a reduction in transmission power required, improvement of reception quality, and an increase in communication capacity achieved.

(2) Except for a fixed period of time, a selected one of the weight sequences alone can be used to simplify the system.

(3) By using the CRC to determine the reliability of data, accurate reliability determination can be achieved.

(4) By using the likelihood obtained during recovery of the FEC to determine the reliability of data, accurate reliability determination can be accomplished.

(5) By using the power or SN ratio of the data sequence during data reliability determination, the reliability can be determined faster and more simply, thereby restraining an increase in hardware scale.

The present invention has been described in detail with respect to various embodiments, and it will now be apparent from the foregoing to those skilled in the art that changes and modifications may be made without departing from the invention in its broader aspects, and it is the intention, therefore, in the appended claims to cover all such changes and modifications as fall within the true spirit of the invention.